

JUNE 2015

NATIONAL GEOGRAPHIC



WEED

THE NEW SCIENCE
OF MARIJUANA

Should Captive
Dolphins
Be Freed?

Dry Times
Are Here for
the Aral Sea

Living
Goddesses
of Nepal



Small Sulawesi Cuscus (*Strigocuscus celebensis*)

Size: Head and body length, 29.4 - 38 cm (11.5 - 15 inches); tail, 27 - 37.3 cm (10.6 - 14.7 inches) **Weight:** Approx. 1 kg (2.2 lb) **Habitat:** Primary and occasionally secondary forests on the islands of Sulawesi, Sangihe and Siau **Surviving number:** Unknown



Photographed by Theo Allots

WILDLIFE AS CANON SEES IT

Master climber. Taking advantage of its strong claws and also grasping branches with its tail, the small Sulawesi cuscus moves easily through the forest canopy. A great deal of foraging time is dedicated to searching out choice leaves and fruit, but the little marsupial also preys on bird nests. This predation plays an important part in the island ecosystem, as does its role as a seed

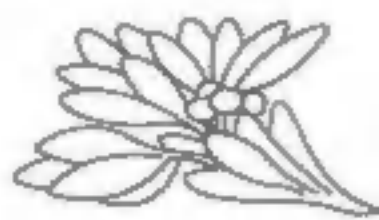
disperser. However, as trees fall with the advance of deforestation and hunters continue to set their sights on the small Sulawesi cuscus, who knows how much longer it can keep climbing?

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.



EOS System

Canon



In Tokha, Nepal, Kumari Dango has been worshipped as a living goddess since she was a baby. She's now nine years old.



78 Living Goddesses of Nepal

In Nepalese tradition a little girl can become a living goddess—but only for so long.

By Isabella Tree Photographs by Stephanie Sinclair

30

High Science

With marijuana's rising acceptance comes more debate about its potential benefits and drawbacks.

By Hampton Sides
Photographs by Lynn Johnson

58

Born to Be Wild

Can dolphins return to the sea after captivity in a marine park? Some can—once they relearn how to be wild.

By Tim Zimmermann

98

Little Park of Wonders

Its world-renowned fossil bed and stunning vistas make Canada's Yoho National Park a standout.

By McKenzie Funk
Photographs by Peter Essick

114

Sins of the Aral Sea

Diverted to water crops, what was once a vast inland sea is 90 percent gone. Can it be revived?

By Mark Synnott
Photographs by Carolyn Drake

132 Proof | Bug-Eyed

A high-powered microscope reveals insect and spider eyes as marvels of adaptation.

Story and Photographs by Martin Geggeli

On the Cover Crossbreeding has yielded countless strains of cannabis. The flowering herb, commonly known as marijuana, can grow up to 16 feet tall. Photo illustration by Bill Marr

Corrections and Clarifications Go to ngm.com/errors

A Hard Look at a Soft Drug

You might remember this TV antidrug ad.

"This is your brain," says a grim-faced guy. He holds up an egg. "This is drugs," he says, gesturing to a skillet on the stove and then cracking the egg into the hot pan. "This is your brain on drugs." The egg sizzles and congeals. "Any questions?"

Well, yes—lots of them. And decades after this crusade aired, relatively few have been answered, especially about marijuana.

Now that nearly half the states in this country allow medical marijuana, voters in four states have legalized pot for recreation, and a majority of Americans favor legalization, research about how marijuana affects our brains and bodies is an urgent issue.

There is less hard science about marijuana than you might think. "For nearly 70 years the plant went into hiding, and medical research largely stopped," Hampton Sides reports in this issue. "In America most people expanding knowledge about cannabis were by definition criminals."

Now, Sides and photographer Lynn Johnson find, "the science of cannabis is experiencing a rebirth. We're finding surprises, and possibly miracles, concealed inside this once forbidden plant."

But the federal government still classifies marijuana as a dangerous Schedule I drug, declaring that, like heroin, it has no accepted medical use. Unless marijuana is reclassified to Schedule II status—allowing it to be studied with fewer restrictions—answers will be slow. Bipartisan bills to change its status have been introduced in both the Senate and House of Representatives; chances of passage are unclear.

Some top-ranking federal health officials privately bemoan the paucity of marijuana science but tiptoe around the subject in public statements. Not so Senator Kirsten Gillibrand of New York, who introduced a bill along with fellow Democratic Senator Cory Booker of New Jersey and Senator Rand Paul, a Kentucky Republican. Marijuana, Gillibrand says, has "always been demonized. But when you focus on patient-centric advocacy and get patients in front of lawmakers, they will realize how stupid the law is... It is absurd we are not permitted to do scientific research." Gillibrand isn't sure if there will be a vote on the bill this year, but she is hoping for a hearing to bring the concerns to light.

The timing couldn't be better. The disconnect between the willingness of some states to regulate, sell, and tax marijuana and the federal reluctance to allow research to progress leaves an increasing number of people without the knowledge to make informed, science-based choices.



At the CannLabs facility in Denver, Colorado, cannabis products undergo rigorous testing for quality control.

Storemags

Susan Goldberg, Editor in Chief

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3 Questions

nationalgeographic.com/3Q

How to Succeed at Science—and at Life

Persis Drell put her mind to math in seventh grade and found she loved it. In college she had a great female physics professor, and physics became “a passion.” Now dean of the School of Engineering at Stanford University, Drell, 59, previously headed the National Accelerator Laboratory there and oversaw cutting-edge research with the world’s most powerful x-ray free-electron laser.

Talk about going into science when few women did.

After four years at an all-women’s college, the first year I went to Berkeley for physics grad school, I was the only woman in my class. What I remember most vividly was being in classrooms with 45 to 50 others and being the only woman. I didn’t raise my hand to ask questions, because if one of the guys asked a stupid question, no one would remember five minutes later, but if I asked a stupid question, everyone would. I got over that, but it left a memory of what that felt like.

How is the United States doing in educating STEM (science, technology, engineering, and math) leaders?

In general, at the graduate level the U.S. is doing rather well. The students in the great research universities today are incredible: No one has ever told them that a problem can’t be solved, so off they go and solve it. But I spent a lot of time in Germany during a recent sabbatical, and I see countries in Europe that are moving very fast to catch up and in some areas potentially surpass the U.S. That worries me.

What advice would you give would-be scientists today?

It’s been a long time since anybody’s tried to marginalize me around a gender issue, but I am sensitive to the fact that for young women it’s not always easy still. And so I take a great deal of pleasure in trying to be supportive and encouraging, particularly when I think young women—and young men too, frankly—have a hard time seeing that they can become successful scientists and have a family life as well.



SYLVIA EARLE



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Science



PIONEERING ROUTE

Taking advantage of shrinking ice cover, companies plan to lay a 9,500-mile cable through the Canadian Arctic, at a price of more than \$600 million.

FASTER, FASTER

The first transatlantic line built since 2003, the Hibernia Express, due in 2015, will cut milliseconds from worldwide financial transactions.

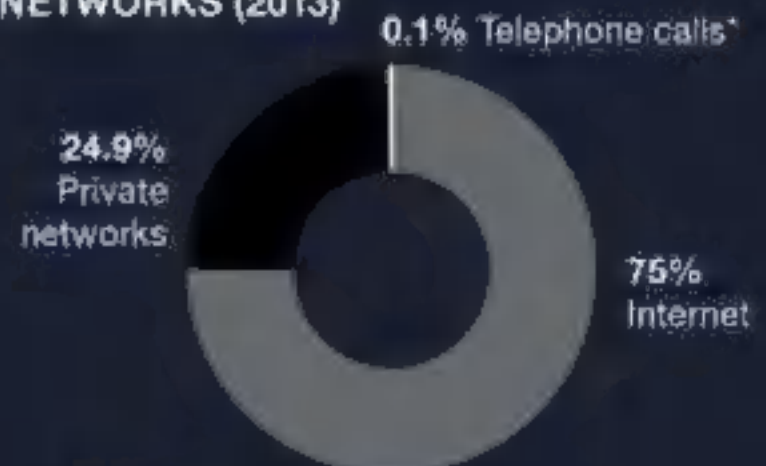
ACCIDENT-PRONE

Globally a cable is damaged on average every few days. Dragging anchors and trawlnets cause most faults. Earthquakes are also a threat.

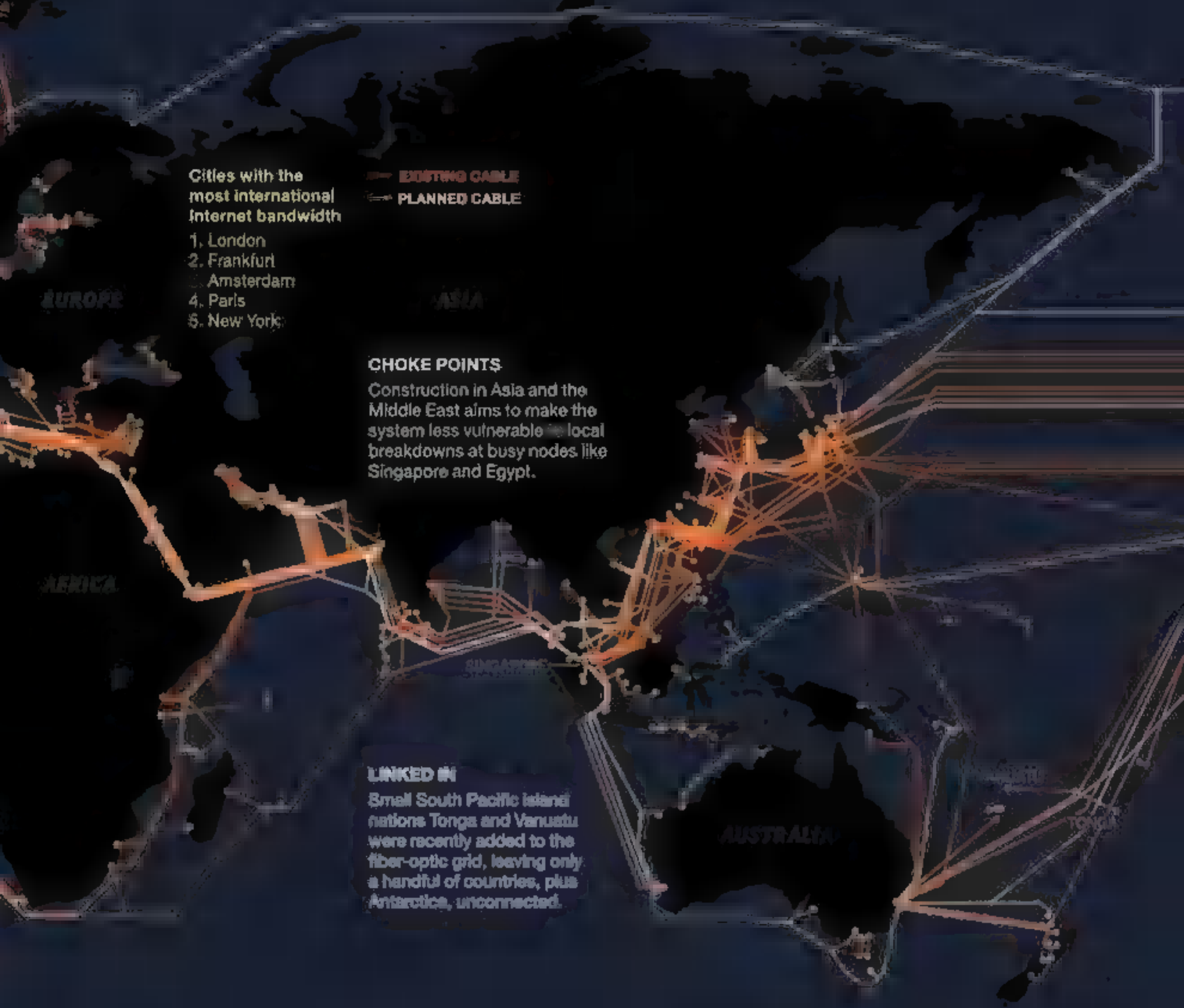
Putting Communications First

The intercontinental superhighway has come a long way since the first copper telegraph line was strung across the Atlantic seabed in 1858, transmitting a few words a minute. Soon the Hibernia Express, the first new transatlantic fiber-optic cable in ten years, will be able to flash the equivalent of 125 years of *National Geographic* magazine in 30 milliseconds. Some 580,000 miles of cables cross the ocean floors, a vast system of fast lines carrying almost all the world's digital traffic. The latest lines link fast developing lands, avoid congestion, and shave milliseconds from connection times. —Tom O'Neill

DATA FLOWING THROUGH NETWORKS (2013)



*CALLS MADE BY VOICE OVER INTERNET PROTOCOL INCLUDED IN OTHER CATEGORIES.



Cities with the most international Internet bandwidth

1. London
2. Frankfurt
3. Amsterdam
4. Paris
5. New York

- EXISTING CABLE
- - - PLANNED CABLE

CHOKES POINTS

Construction in Asia and the Middle East aims to make the system less vulnerable to local breakdowns at busy nodes like Singapore and Egypt.

LINKED IN

Small South Pacific island nations Tonga and Vanuatu were recently added to the fiber-optic grid, leaving only a handful of countries, plus Antarctica, unconnected.

SUBMARINE CABLE ANATOMY

- Optical fibers
- Silicone gel
- High-strength steel
- Copper sheath
- Polyethylene
- Galvanized armor wires
- Reinforced cotton yarn

LEAP OF BANDWIDTH

Global bandwidth soared 16-fold in 2014. Europe's bank of cables, the Middle East and Africa saw the fastest growth.

185 Terabits per second

11.1

2007

2014



Lotion in the Ocean

The sunscreen you put on your skin doesn't stay there. Up to 6,600 tons of sunscreen wash into coastal waters each year. That's bad news for swimmers, who end up unprotected from the sun—and also for fish, according to a report from the Spanish Research Council. When nanoparticles from one of sunscreen's main ingredients, titanium dioxide, mix with water and sun, the result is hydrogen peroxide. It kills phytoplankton that nourish fish and, ultimately, the rest of the food chain.

Researchers don't encourage people to wear less sunscreen. The solution is for producers to create eco-friendly substitutes, says marine ecologist Cinzia Corinaldesi. For more than a decade, sunscreen makers have been on the hunt for a new chemical formula that hardly leaves a trace. —Daniel Stone



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Koalas Keep Cool

When things heat up down under, koalas know how to keep their cool. Now, thanks to infrared photography, humans can see how they do it.

A 2014 study led by University of Melbourne ecologists showed that when summer temperatures climb up—often above 104°F—koalas climb down, pressing their bodies close to the trunks of trees. Each tree has its own microclimate, says researcher Natalie Briscoe, and can be more than 12°F cooler than the air. So for a koala, whose belly fur is relatively thin, tree hugging is like standing in front of an open fridge. As a way to regulate body temperature, it's more efficient than panting or fur licking—koala-cooling methods that use twice as much water.

In a separate study, University of Sydney biologist Mathew Crowther found that koalas tend to chill out in “shelter trees” like casuarina rather than in “food trees” like eucalyptus. But in a heat wave either will do. As extreme heat becomes more frequent, tree hugging could become even more crucial. —*Jeremy Berlin*



3-D DODO RESURRECTION

As technology gives dodos a closer look, their image may get a second chance.

College of the Holy Cross paleontologist Leon Claessens and a team of researchers recently used a 3-D laser scanner on the world's only complete dodo skeleton. The result—the first digitized dodo—may answer age-old questions about how the three-foot-tall, flightless birds looked, walked, and behaved.

“The dodo's rep as an evolutionary failure is entirely undeserved,” Claessens says. Dodos thrived on Mauritius for thousands of years before the Dutch came in 1598. By 1693 dodos were extinct, “a case study of human disruption.” —*JB*

Started my Camry.
Rescued a dog.
Searched for the owners.
Uncovered a plot.
Escaped with the evidence.
Took a leap of faith.
Left them all behind.
Kept the dog.

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EXPLORE

Planet Earth: By the Numbers

Reefs at Risk

Coral reefs are among the world's most at-risk ecosystems, and among the biggest threats to them is climate change. Rising water temperatures contribute to coral bleaching and die-offs, and acidification makes it hard for coral polyps to build the skeletons that form the reef.

"Climate change can distress even the best managed and most remote reefs," says Mark Eakin of the National Oceanic and Atmospheric Administration. Local activities—coastal development, overfishing, pollution—can also hurt corals. But good management can make reefs more resilient, allowing them to bounce back if conditions improve. —Kelsey Nowakowski

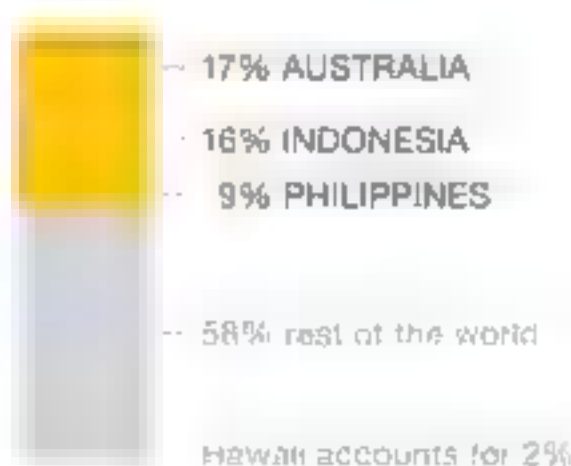
WORLDWIDE REEFS

25%

OF MARINE FISH SPECIES LIVE IN REEFS

25% of marine fish species live in reefs, compared to 2% of mammals and 1% of birds. The number of species found in tropical rainforests is similar to the number of species found in coral reefs.

DISTRIBUTION



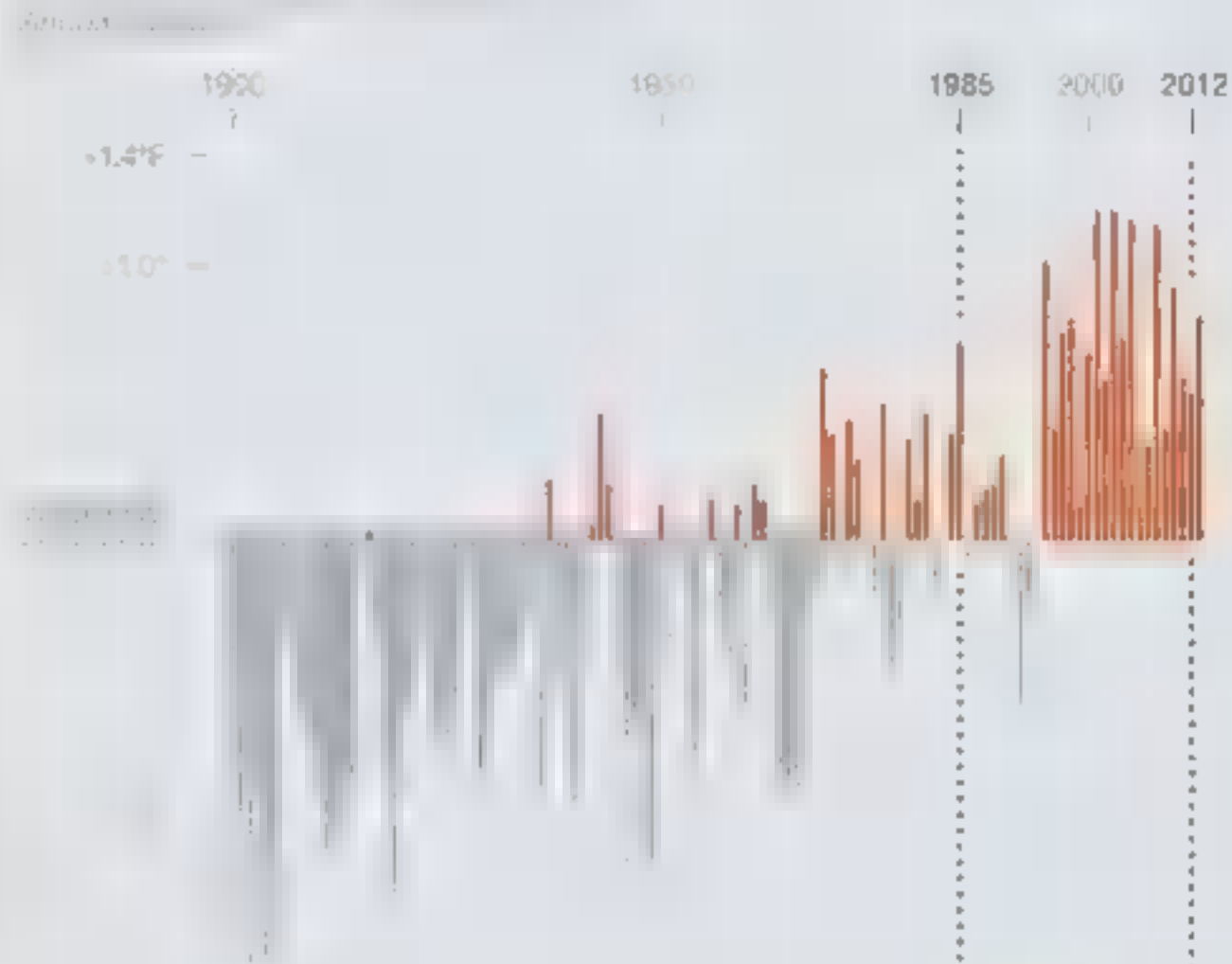
THE GREAT BARRIER REEF

Great Barrier Reef



Stretching more than 1,400 miles, this reef system—the world's largest—is under pressure from climate change. Sea-temperature rise, acidification, and more intense weather events such as cyclones are putting the reef's more than 400 corals and 1,500 fish species at risk.

CORAL SEA SUMMER TEMPERATURES

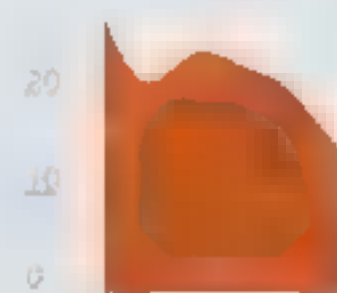


CORAL COVER LOSS

1/2

A study led by the Australian Institute of Marine Science found that between 1985 and 2012 the reef lost half its coral cover, or living polyps.

% Coral cover



1. Great Barrier Reef
2. Phoenix Islands Passage
3. Tonga and Tokelau
4. Christmas Island
5. Phoenix Islands
6. Phoenix Islands
7. Phoenix Islands
8. Phoenix Islands
9. Phoenix Islands
10. Phoenix Islands



CORAL BLEACHING

Bleaching is a top cause of coral death. In 1998 rising water temperatures killed 16 percent of the world's coral reefs. Warming water triggered widespread bleaching in 2014, but scientists are still calculating the damage.

HEALTHY CORAL

Most polyps have a symbiotic relationship with the algae that live in them and provide up to 90 percent of their food. Algae also give corals their color.

BLEACHED CORAL

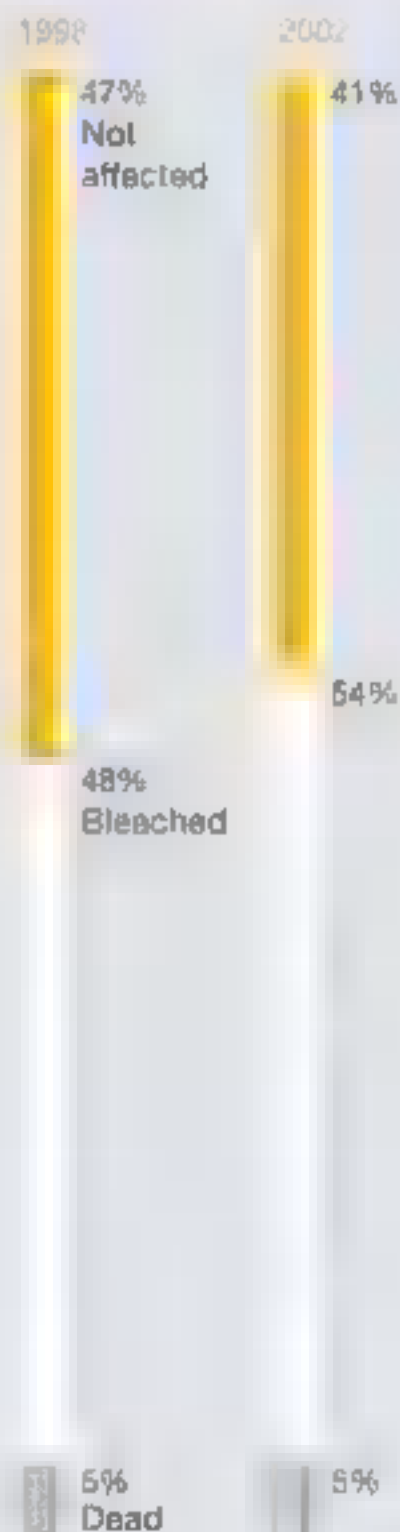
When water temperatures rise one to two degrees above normal warm-season levels, corals lose the algae, or zooxanthellae, revealing a white skeleton.

DEAD CORAL

Without the algae, most corals struggle to feed themselves and can die. Turf algae can easily colonize the polyps and overgrow them.

GREAT BARRIER REEF MASS BLEACHING*

Events caused by sea-temperature rise



*Estimates based on surveyed reefs



WHAT'S AT RISK

The loss of coral reefs could have a significant impact on the world's economy and environment.



One-eighth of the world's population relies on fisheries and coral reefs for food and income.



Number of countries and territories that rely on coral reefs for tourism.

\$11.5 billion

Annual global revenues from tourism linked to reefs

For people with a higher risk of stroke due to Atrial Fibrillation (AFib) not caused by a heart valve problem

I won't accept going for less than my personal best.



ELIQUIS[®] (apixaban) is a prescription medicine used to reduce the risk of stroke and blood clots in people who have atrial fibrillation, a type of irregular heartbeat, not caused by a heart valve problem.

IMPORTANT SAFETY INFORMATION:

- Do not stop taking ELIQUIS for atrial fibrillation without talking ■ the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke. ELIQUIS may need to be stopped, prior to surgery or ■ medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.
- ELIQUIS can cause bleeding, which can be serious, and rarely may lead to death.
- You may have a higher risk of bleeding ■ you take ELIQUIS and take other medicines that increase your risk of bleeding, such as aspirin, NSAIDs, warfarin (COUMADIN[®]), heparin, SSRIs or SNRIs, and other blood thinners. Tell your doctor about all medicines, vitamins and supplements you take.

While taking ELIQUIS, you may bruise more easily and it may take longer than usual for any bleeding to stop.

- Get medical help right away if you have any of these signs or symptoms of bleeding:
 - unexpected bleeding, or bleeding that lasts ■ long time, such as unusual bleeding from the gums; nosebleeds that happen often, or menstrual ■ vaginal bleeding that is heavier than normal
 - bleeding that is severe or you cannot control
 - red, pink, or brown urine; red or black stools (looks like tar)
 - coughing up or vomiting blood or vomit that looks like coffee grounds
 - unexpected pain, swelling, or joint pain; headaches, feeling dizzy or weak
- ELIQUIS is not for patients with artificial heart valves.

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than warfarin.

No routine blood testing.

ELIQUIS and other blood thinners increase the risk of bleeding which can be serious, and rarely may lead to death.

Ask your doctor if ELIQUIS is right for you.

● **Spinal or epidural blood clots (hematoma).** People who take ELIQUIS, and have medicine injected into their spinal and epidural area, or have a spinal puncture have a risk of forming a blood clot that can cause long-term or permanent loss of the ability to move (paralysis). This risk is higher if, an epidural catheter is placed in your back to give you certain medicine, you take NSAIDs or blood thinners, you have a history of difficult or repeated epidural or spinal punctures. Tell your doctor right away if you have tingling, numbness, or muscle weakness, especially in your legs and feet.

● **Before you take ELIQUIS,** tell your doctor if you have: kidney or liver problems, any other medical condition, or ever had bleeding problems. Tell your doctor if you are pregnant or breastfeeding, or plan to become pregnant or breastfeed.

● **Do not take ELIQUIS** if you currently have certain types of abnormal bleeding or have had a serious allergic reaction to ELIQUIS.

A reaction to ELIQUIS can cause hives, rash, itching, and possibly trouble breathing. Get medical help right away if you have sudden chest pain or chest tightness, have sudden swelling of your face or tongue, have trouble breathing, wheezing, or feeling dizzy or faint.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

Please see additional Important Product Information on the adjacent page.

Individual results may vary.

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Eliquis.
(apixaban) tablet

IMPORTANT FACTS about ELIQUIS® (apixaban) tablets

Rx ONLY

The information below does not take the place of talking with your healthcare professional. Only your healthcare professional knows the specifics of your condition and how ELIQUIS may fit into your overall therapy. Talk to your healthcare professional if you have any questions about ELIQUIS (pronounced ELL eh kwiss).

What is the most important information I should know about ELIQUIS (apixaban)?

For people taking ELIQUIS for atrial fibrillation: Do not stop taking ELIQUIS without talking to the doctor who prescribed it for you. Stopping ELIQUIS increases your risk of having a stroke. ELIQUIS may need to be stopped, prior to surgery or a medical or dental procedure. Your doctor will tell you when you should stop taking ELIQUIS and when you may start taking it again. If you have to stop taking ELIQUIS, your doctor may prescribe another medicine to help prevent a blood clot from forming.

ELIQUIS can cause bleeding which can be serious, and rarely may lead to death. This is because ELIQUIS is a blood thinner medicine that reduces blood clotting.

You may have a higher risk of bleeding if you take ELIQUIS and take other medicines that increase your risk of bleeding, such as aspirin, nonsteroidal anti-inflammatory drugs (called NSAIDs), warfarin (COUMADIN®), heparin, selective serotonin reuptake inhibitors (SSRIs) or serotonin norepinephrine reuptake inhibitors (SNRIs), and other medicines to help prevent or treat blood clots.

Tell your doctor if you take any of these medicines. Ask your doctor or pharmacist if you are not sure if your medicine is one listed above.

While taking ELIQUIS:

- you may bruise more easily
- it may take longer than usual for any bleeding to stop

Call your doctor or get medical help right away if you have any of these signs or symptoms of bleeding when taking ELIQUIS:

- unexpected bleeding, or bleeding that lasts a long time, such as:
 - unusual bleeding from the gums
 - nosebleeds that happen often
 - menstrual bleeding or vaginal bleeding that is heavier than normal

- bleeding that is severe or you cannot control
- red, pink, or brown urine
- red or black stools (looks like tar)
- cough up blood or blood clots
- vomit blood or your vomit looks like coffee grounds
- unexpected pain, swelling, or joint pain
- headaches, feeling dizzy or weak

ELIQUIS (apixaban) is not for patients with artificial heart valves.

Spinal or epidural blood clots (hematoma). People who take a blood thinner medicine (anticoagulant) like ELIQUIS, and have medicine injected into their spinal and epidural area, or have a spinal puncture have a risk of forming a blood clot that can cause long-term or permanent loss of the ability to move (paralysis). Your risk of developing a spinal or epidural blood clot is higher if:

- a thin tube called an epidural catheter is placed in your back to give you certain medicine
- you take NSAIDs or a medicine to prevent blood from clotting
- you have a history of difficult or repeated epidural or spinal punctures
- you have a history of problems with your spine or have had surgery on your spine

If you take ELIQUIS and receive spinal anesthesia or have a spinal puncture, your doctor should watch you closely for symptoms of spinal or epidural blood clots or bleeding. Tell your doctor right away if you have tingling, numbness, or muscle weakness, especially in your legs and feet.

What is ELIQUIS?

ELIQUIS is a prescription medicine used to:

- reduce the risk of stroke and blood clots in people who have atrial fibrillation.
- reduce the risk of forming a blood clot in the legs and lungs of people who have just had hip or knee replacement surgery.

(Continued on adjacent page)



PATIENT ASSISTANCE FOUNDATION

This independent, non-profit organization provides assistance to qualifying patients with financial hardship who generally have no prescription insurance. Contact 1-800-736-0003 or visit www.bmspaf.org for more information.

IMPORTANT FACTS about ELIQUIS® (apixaban) tablets (Continued)

- treat blood clots in the veins of your legs (deep vein thrombosis) or lungs (pulmonary embolism), and reduce the risk of them occurring again.

It is not known if ELIQUIS is safe and effective in children.

Who should not take ELIQUIS (apixaban)?

Do not take ELIQUIS if you:

- currently have certain types of abnormal bleeding
- have had a serious allergic reaction to ELIQUIS. Ask your doctor if you are not sure

What should I tell my doctor before taking ELIQUIS?

Before you take ELIQUIS, tell your doctor if you:

- have kidney or liver problems
- have any other medical condition
- have ever had bleeding problems
- are pregnant or plan to become pregnant. It is not known if ELIQUIS will harm your unborn baby
- are breastfeeding or plan to breastfeed. It is not known if ELIQUIS passes into your breast milk. You and your doctor should decide if you will take ELIQUIS or breastfeed. You should not do both

Tell all of your doctors and dentists that you are taking ELIQUIS. They should talk to the doctor who prescribed ELIQUIS for you, before you have **any** surgery, medical or dental procedure. **Tell your doctor about all the medicines you take, including** prescription and over-the-counter medicines, vitamins, and herbal supplements. Some of your other medicines may affect the way ELIQUIS works. Certain medicines may increase your risk of bleeding or stroke when taken with ELIQUIS.

How should I take ELIQUIS?

Take ELIQUIS exactly as prescribed by your doctor. Take ELIQUIS twice every day with or without food, and do not change your dose or stop taking it unless your doctor tells you to. If you miss a dose of ELIQUIS, take it as soon as you remember, and do not take more than one dose at

the same time. **Do not run out of ELIQUIS. Refill your prescription before you run out.** When leaving the hospital following hip or knee replacement, be sure that you will have ELIQUIS (apixaban) available to avoid missing any doses. **If you are taking ELIQUIS for atrial fibrillation, stopping ELIQUIS may increase your risk of having a stroke.**

What are the possible side effects of ELIQUIS?

- See “**What is the most important information I should know about ELIQUIS?**”
- ELIQUIS can cause a skin rash or severe allergic reaction. Call your doctor or get medical help right away if you have any of the following symptoms:
 - chest pain or tightness
 - swelling of your face or tongue
 - trouble breathing or wheezing
 - feeling dizzy or faint

Tell your doctor if you have any side effect that bothers you or that does not go away.

These are not all of the possible side effects of ELIQUIS. For more information, ask your doctor or pharmacist.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

This is a brief summary of the most important information about ELIQUIS. For more information, talk with your doctor or pharmacist, call 1-855-ELIQUIS (1-855-354-7847), or go to www.ELIQUIS.com.

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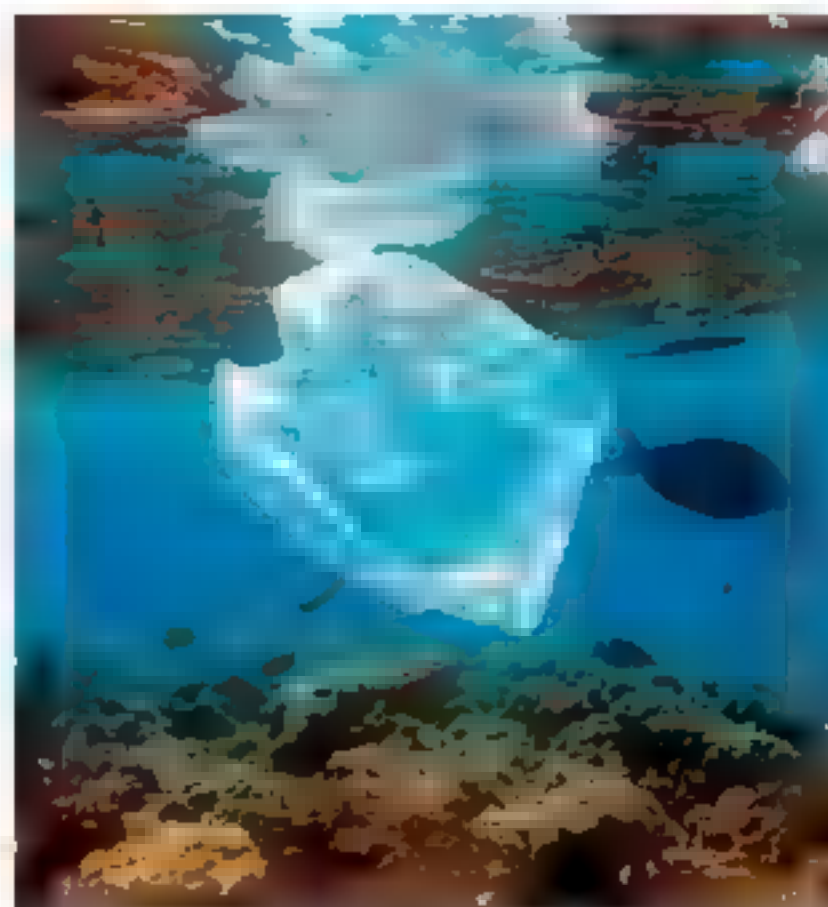


(Re)parting the Seas

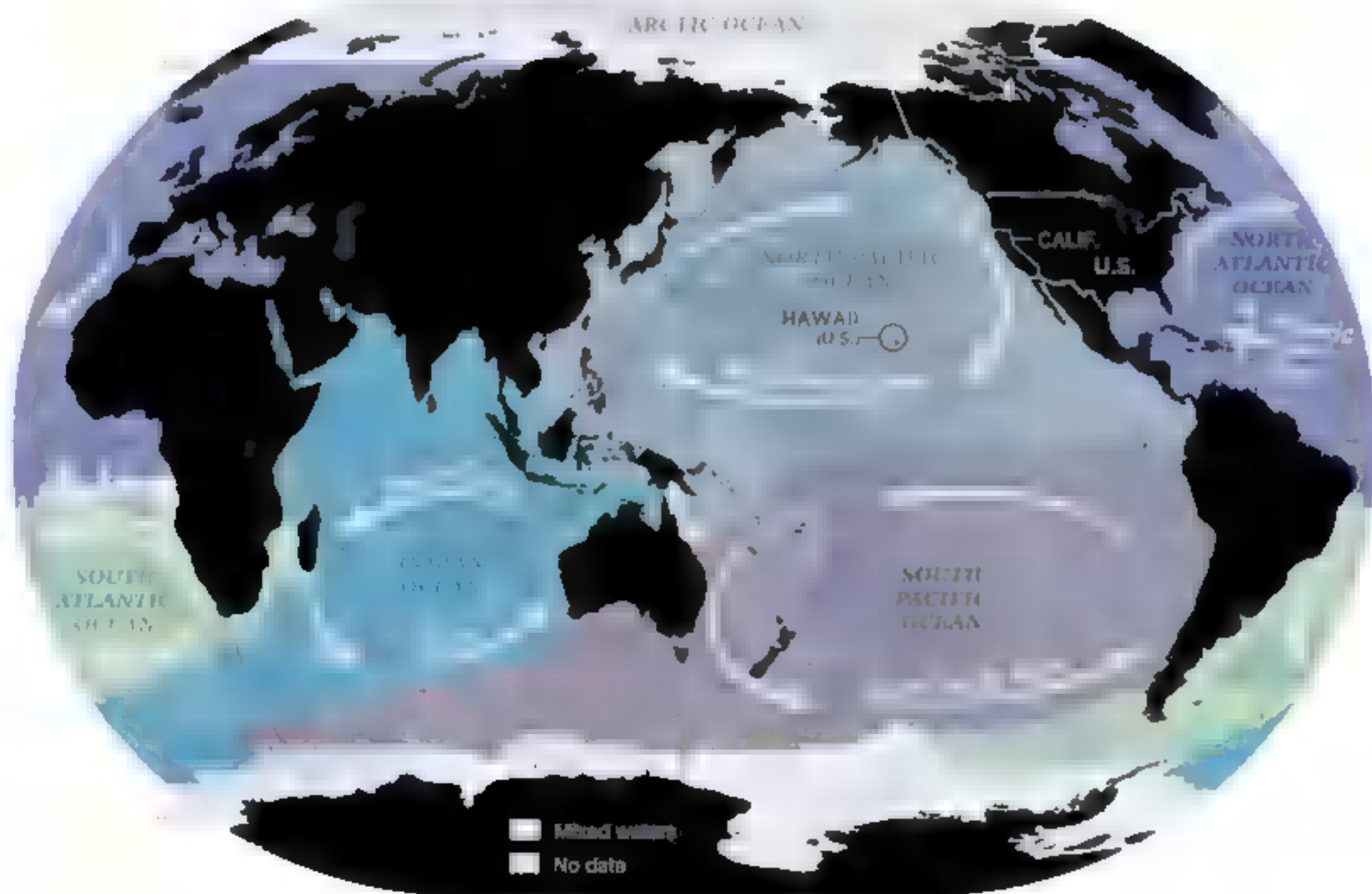
For something that covers most of the planet, the ocean is a pretty murky frontier. Scientists say technically there's just one connected global ocean, but people far more commonly refer to several, as in the Atlantic, the Pacific, the Indian.

More confusing is why the lines separating these basins—divisions first formally recognized in 1928—have remained largely unchanged. “The boundaries reflect geopolitics” rather than the way the water actually circulates, says mathematician Gary Froyland of Australia’s University of New South Wales. He and Imperial College oceanographer Erik van Sebille proposed a new map, redrawing borders based on modern knowledge of currents and the natural basins they form, as well as the currents’ relationship to a pressing environmental problem: trash.

Plastics and other debris have been drifting for decades in the oceans, sometimes churned into massive patches by powerful currents known as gyres. Froyland and van Sebille’s revised boundaries center roughly on the locations of these polluted plots, the largest of which floats between Hawaii and California. With further research, their new analysis could help determine the origins of some of the litter—in other words, which countries are responsible for dumping it. —Catherine Zuckerman



Plastic bottles, bags, bottles, and other debris are scattered in the ocean, often in massive patches. Scientists are studying how plastic pollution flows. (Illustration by Peter J. Parnham)



world beat

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CANON IMAGING PLAZA

Canon launched the Canon Imaging Plaza YouTube channel as a resource for photo enthusiasts to learn more about digital photography, Canon products, and the fun and joy of capturing images and videos with a digital camera. Canon believes that dedicated digital cameras provide users with the best means of capturing life's special moments.

Learn more at
youtube.com/user/canonimagingplaza.

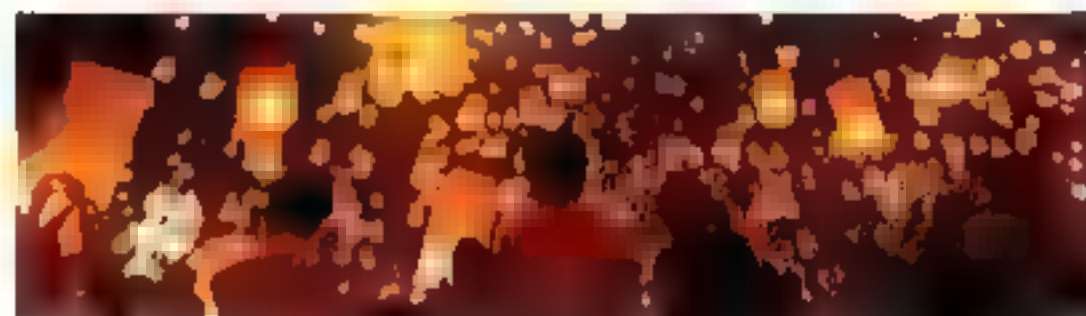


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Dinosaur Mystery

Dissecting ■ Dino?
Watch *T. Rex Autopsy*
on the National Geo-
graphic Channel on
June 7, 9 p.m. ET/PT.

At first glance, a 120-million-year-old fossil from northeastern China appears to be a nest of babies with an older companion, perhaps a sibling babysitter. "I see that as easily as everyone else," says paleontologist Brandon Hedrick, who studied the unusual group recently. Farmers had excavated the fossil, which is almost three feet across, but they didn't get surrounding features, such as the edge of a nest, that would help explain what the dinosaurs were doing. The more Hedrick dug into the details, the less this looked like a bunch of nest mates.

He offers two other possibilities. The dinosaurs may have been hiding in a burrow that collapsed and crushed them. Their species—named *Psittacosaurus*, or "parrot lizard," for their large beaks—perhaps lived in large herds. "They were extremely successful," he says. "They were found across Asia, and all the carnivorous dinosaurs that were living at the time must have loved to eat them."

But there's a more likely scenario, given the positions of the bodies and the nature of the rock surrounding them: The creatures were victims of a mudslide that suddenly swept them up and carried them to their death. —A. R. Williams



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It took three years of development and \$26 million in advanced Swiss-built watch-making machinery to create the *Magnificat II*. Look at the interior dials and azure-colored hands. Turn the watch over and examine the 27-jeweled automatic movement through the exhibition back. When we took the watch to George Thomas (the most renowned watchmaker and watch historian in America), he disassembled the *Magnificat II* and estimated that this fine timepiece would cost over \$2,500.

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If you purchased Wallboard INDIRECTLY from one or more of the companies listed below, your rights may be affected by proposed Settlements

Proposed class settlements totaling \$10.5 million have been reached with two Defendants in *In re Domestic Drywall Antitrust Litigation*, MDL No. 2437 and 13-MD-2437, pending in the U.S. District Court for the Eastern District of Pennsylvania.

If you purchased for end use wallboard manufactured and/or distributed by CertainTeed Gypsum, Inc., USG Corporation, United States Gypsum Company, New NGC, Inc., Lafarge North America, Inc., Eagle Materials, Inc., American Gypsum Company LLC, PABCO Building Products, LLC, TTN, Inc., or their subsidiaries (collectively, the "Defendants"), between January 1, 2012 and November 30, 2014, you may be a class member. "Wallboard" means paper-backed gypsum wallboard, also called drywall or plasterboard.

What is the lawsuit about? Plaintiffs allege that Defendants violated state and federal laws by fixing wallboard prices, causing Class Members to pay inflated prices. Plaintiffs seek damages, injunctive relief, and attorneys' fees and expenses. Defendants deny Plaintiffs' allegations, and the Court has not determined who is right. Plaintiffs have reached separate agreements to settle the lawsuit with (1) TTN Inc. ("TTN") and (2) USG Corporation, United States Gypsum Company, and USG Corporation's subsidiary L&W Supply Corporation (collectively, "USG"). Litigation continues against the other Defendants.

Who is included? The TTN and USG Settlement Classes each include all persons or entities that indirectly purchased for end use and not for resale wallboard in the United States manufactured or distributed by the Defendants or their subsidiaries from January 1, 2012 through November 30, 2014. The settlements recover money for Class Members in Arizona, Arkansas, California, the District of Columbia, Florida, Illinois, Iowa, Kansas, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New Hampshire, New Mexico, New York, North Carolina, North Dakota, Puerto Rico, Rhode Island, South Dakota, Tennessee, Utah, Vermont, West Virginia, and Wisconsin. Excluded are Defendants, their parent companies, subsidiaries, affiliates, officers, directors and employees, any federal governmental entities and instrumentalities, any judicial officer presiding over the Action, any member of his or her immediate family and judicial staff, and any juror assigned to the Action.

What do the settlements provide? In exchange for their release and dismissal, TTN will pay \$1.75 million, and USG will pay \$8.75 million. Each defendant has agreed to provide cooperation with Plaintiffs as set forth in their respective settlement agreements.

Your rights may be affected. If you are a member of either Settlement Class and wish to remain in it, you do not need to take any action now, and your interests will be represented by Plaintiffs and Class Counsel.

If you do not want to be bound by one or both settlements, you must submit a written request for exclusion, **postmarked no later than June 30, 2015**. If you exclude yourself from a Settlement Class, you will not be a part of the settlement with that defendant, but will preserve your right to file or maintain your own lawsuit against it and will not be bound by any judgment dismissing it. Excluding yourself will not affect your rights regarding non-settling Defendants.

If you do not opt out, you can object to a settlement's terms or to Plaintiffs' request to utilize up to \$2.5 million of the settlement funds to pay litigation expenses. Your objection must be filed **no later than June 30, 2015**.

More information on objecting or requesting exclusion is available at www.IndirectDrywallSettlement.com.

The Court will hold a final approval hearing on July 15, 2015 at 10 a.m. at the James A. Byrne United States Courthouse, 601 Market Street, Philadelphia, PA 19106, Courtroom 3A. The hearing may be continued without notice.

Further information is available at www.IndirectDrywallSettlement.com, or you may call 1-855-229-7511.

Do not contact the Court.

Dated: March 16, 2015 BY ORDER OF:
The United States District Court
for the Eastern District of Pennsylvania

www.IndirectDrywallSettlement.com
1-855-229-7511

Basic Instincts

A genteel disquisition on love and lust in the animal kingdom.

What She Demands, He Does

Lemurs come from one of the oldest branches of the primate family tree: Their ancestors date from the Eocene, as long as 55 million years ago. Intelligent creatures, they've had epochs to evolve, adopt beneficial behaviors, and refine social systems. Where have they wound up? With the females in charge.

Though matriarchy is rare in primates, female dominance is the norm for most lemur species, including the Coquerel's sifaka, seen here. Even the youngest females can pull rank on any male, and females get first choice of foods and resting sites, says Chris Smith of the Duke Lemur Center. "We've seen females take food out of males' mouths. And if he's in a sunny spot she wants, she can just move toward him, and he'll make a submissive cackle and get out of the way." If a male displeases her, a female may push or slap him or rip his fur out. For the brief period each year when they want to mate, females "are little hussies," says Duke University lemur researcher Lydia Greene. "They completely control which mates they want and how many."

Neither sex will dominate, though, unless lemurs' prospects improve. In their native Madagascar they've lost 90 percent of their habitat, chiefly to slash-and-burn agriculture. Of the 103 surviving lemur species and subspecies, 20 are vulnerable, 49—including the Coquerel's sifaka—are endangered, and 24 are critically endangered. —Patricia Edmonds

HABITAT/RANGE

Forests of Madagascar

CONSERVATION STATUS

Lemurs are the world's most endangered mamma

OTHER FACTS

New lemur species are still being discovered. The Coquerel's sifaka has a gestation period of about 100 days and gives birth to one pup per

If a male displeases her, a female may push or slap him or rip his fur out.

This Coquerel's sifaka (*Propithecus coquereli*) was photographed at the Houston Zoo.

PHOTO: JOELI SARTORE, NATIONAL GEOGRAPHIC CREATIVE





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Jack says only BRAVECTO® provides up to 12 weeks* of flea & tick protection in a tasty chew. Talk to the expert on all things dog—your vet.

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*Bravecto kills fleas, prevents flea infestations, and kills ticks (black-legged tick, American dog tick, and brown dog tick) for 12 weeks. Bravecto also kills lone star ticks for 8 weeks.

Bravecto is for dogs 6 months of age or older. Side effects may include vomiting, decreased appetite, diarrhea, lethargy, excessive thirst, and flatulence.

Please see Brief Summary of Prescribing Information on following page.

 **MERCK**
Animal Health

NADA 141-426, Approved by FDA

BRAVECTO
(FLURALANER)

BRIEF SUMMARY (For full Prescribing Information, see package insert)

Caution:

Federal (USA) law restricts this drug to use by or on the order of a licensed veterinarian.

Indications:

Bravecto kills adult fleas and is indicated for the treatment and prevention of flea infestations (*Ctenocephalides felis*) and the treatment and control of tick infestations (*Ixodes scapularis* [black-legged tick], *Dermacentor variabilis* [American dog tick], and *Rhipicephalus sanguineus* [brown dog tick]) for 12 weeks in dogs and puppies 6 months of age and older, and weighing 4.4 pounds or greater.

Bravecto is also indicated for the treatment and control of *Amblyomma americanum* [lone star tick] infestations for 8 weeks in dogs and puppies 6 months of age and older, and weighing 4.4 pounds or greater.

Contraindications:

There are no known contraindications for the use of the product.

Warnings:

Not for human use. Keep this and all drugs out of the reach of children. Keep the product in the original packaging until use, in order to prevent children from getting direct access to the product. Do not eat, drink or smoke while handling the product. Wash hands thoroughly with soap and water immediately after use of the product.

Precautions:

Bravecto has not been shown to be effective for 12-weeks duration in puppies less than 6 months of age. Bravecto is not effective against *Amblyomma americanum* ticks beyond 8 weeks after dosing.

Adverse Reactions:

In a well-controlled U.S. field study, which included 294 dogs (224 dogs were administered Bravecto every 12 weeks and 70 dogs were administered an oral active control every 4 weeks and were provided with a tick collar), there were no serious adverse reactions. All potential adverse reactions were recorded in dogs treated with Bravecto over a 182-day period and in dogs treated with the active control over an 84-day period. The most frequently reported adverse reaction in dogs in the Bravecto and active control groups was vomiting.

Percentage of Dogs with Adverse Reactions in the Field Study

Adverse Reaction (AR)	Bravecto Group: Percentage of Dogs with the AR During the 182-Day Study (n=224 dogs)	Active Control Group: Percentage of Dogs with the AR During the 84-Day Study (n=70 dogs)
Vomiting	7.1	14.3
Decreased Appetite	6.7	0.0
Diarrhea	4.9	2.9
Lethargy	5.4	7.1
Polydipsia	0.9	4.3
Flatulence	1.3	0.0

In a well-controlled laboratory dose confirmation study, one dog developed edema and hyperemia of the upper lips within one hour of receiving Bravecto. The edema improved progressively through the day and had resolved without medical intervention by the next morning.

For technical assistance or to report a suspected adverse drug reaction, contact Merck Animal Health at 1-800-224-5318. Additional information can be found at www.bravecto.com. For additional information about adverse drug experience reporting for animal drugs, contact FDA at 1-888-FDA-VETS or online at <http://www.fda.gov/AnimalVeterinary/SafetyHealth>.

How Supplied:

Bravecto is available in five strengths (112.5, 250, 500, 1000, and 1400 mg fluralaner per chew). Each chew is packaged individually into aluminum foil blister packs sealed with a peelable paper backed foil lid stock. Product may be packaged in 1, 2, or 4 chews per package.

Distributed by:

Intervet Inc (d/b/a Merck Animal Health)
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sits quiet, but this unique piece of American natural history continues to erupt with gorgeous green fire.

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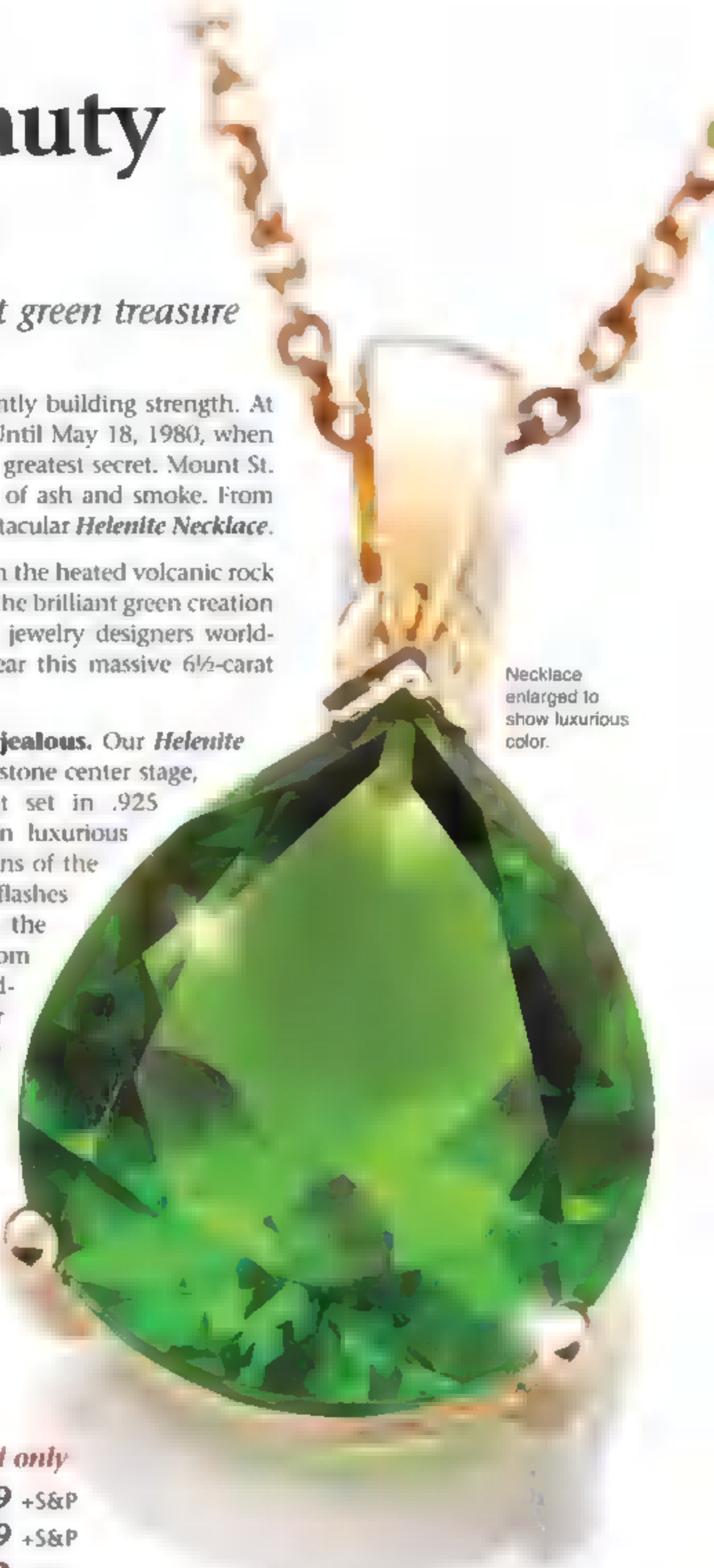
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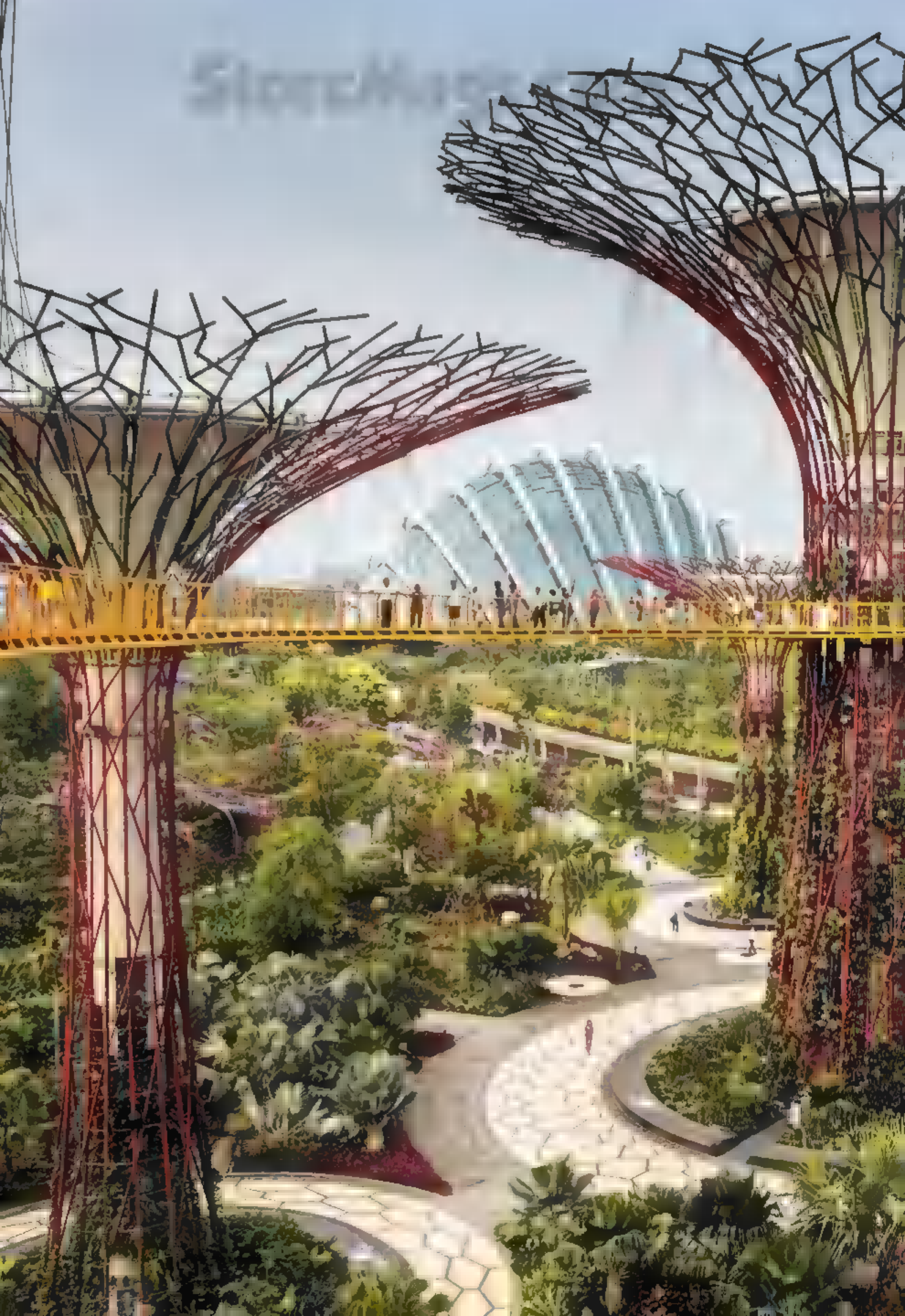




Ukraine

At the Kachalka outdoor gym in Kiev, a former Soviet gymnast shows he's still limber at 83. The makeshift fitness area—several acres of salvaged metal, rubber, and wood in the restive capital—has been free to use since it opened in the 1970s.

PHOTO: FILIP BINGER, EPA





Singapore
Man-made "supertrees" range in height from 82 to 164 feet at Gardens by the Bay. Covering 250 acres, the three-year-old ecotourism site promotes clean water, solar energy, sustainable practices, and botanical diversity.

PHOTO: LUCA LOCATELLI
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PHOTO: PAUL SOUTHERS
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Editor's Choice

Daily Dozen Editors pick 12 photos from those submitted online each day. Here are our favorites this month.



John Trent
Dorchester, England

Trent saw a flamingo while visiting a Florida amusement park. He approached it late in the day after the crowd had thinned. "Photographing the whole bird was never my intention," he says. "All the expression was in the head and wings."



✓Yes



✓Yes



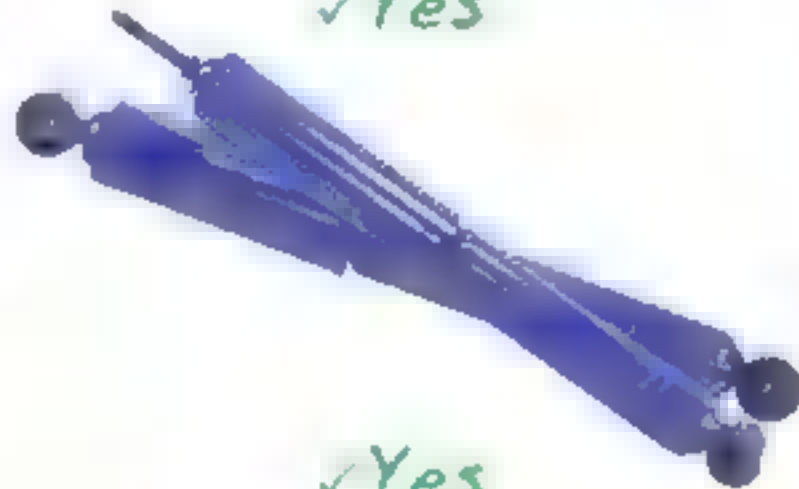
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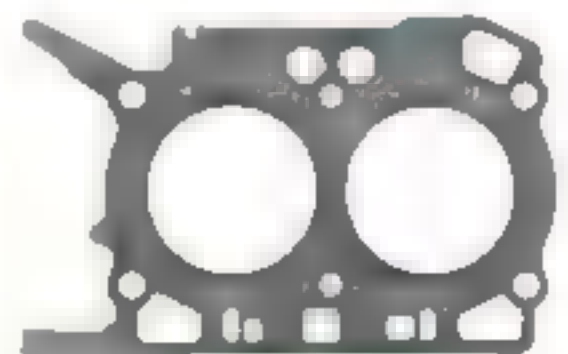
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VISIONS

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Jismon P.

Thiruvananthapuram, India

In a zoo in his hometown, the photographer saw a large herd of deer assemble for a midafternoon feeding. He shot the photo in color, then converted it to black and white to highlight the animals' spotted coats.

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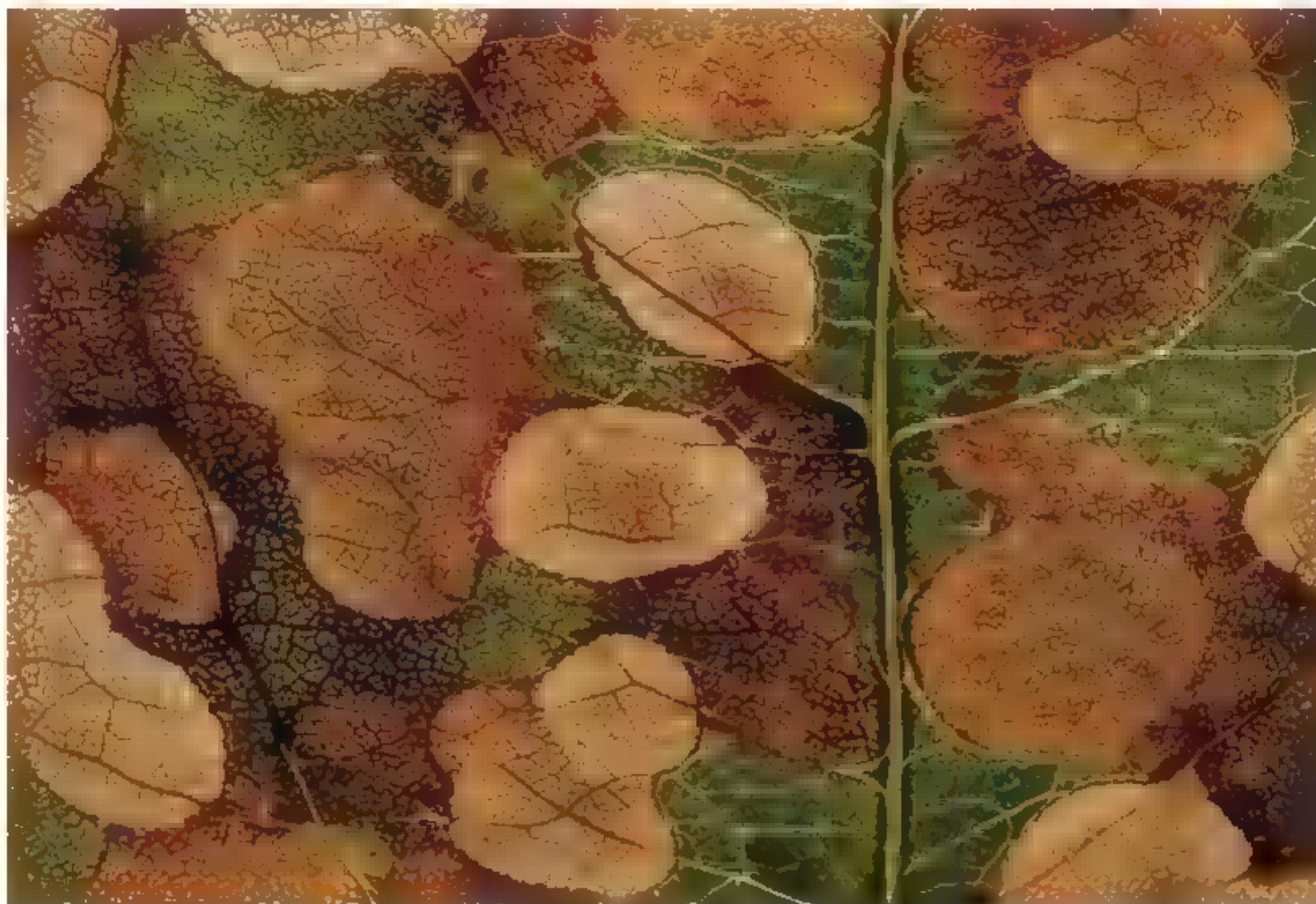
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U.S. GOLD

U.S. GOLD

Macro World

Assignment This month we asked the Your Shot community to get up close and photograph details that the naked eye cannot see.



EDITOR'S NOTE

"Macro photography has the power to transport us into tiny new worlds. I selected photographs that contained some new element that kept me lingering on the scene."

—David Vanden, National Geographic photographer

Ivan Lesica Forest Hills, New York

On a street near his aunt's house, Lesica spotted unusual-looking leaves on a tree. He held one up to the sun, then photographed its patches of color.

Igor Kovalenko Ames, Iowa

Kovalenko learned from a nature documentary that female ichneumon wasps can drill into wood. When he spotted several in his backyard, he set up a macro shot and external flash to catch them in action. "The best frame had two wasps," he says.

As marijuana goes mainstream, claims about its medical benefits proliferate. But what do we really know?

High Science

Marijuana's advocates believe the long-maligned plant can enhance life — and help deliver people from sickness and



ince





Lily Rowland receives a dose of an oil derived mainly from cannabidiol (CBD), a nonpsychoactive substance in marijuana. She used to suffer hundreds of seizures with violent convulsions every day. Her family moved to Colorado, which voted to legalize marijuana in 2012, so that she could begin a daily regimen. The drug doesn't work for everyone, but today nine-year-old Lily ■ often seizure free and on her worst days has only one or two.





Phillip Hague, the chief horticulturist at a Denver cannabis company called Mindful, sniffs the roots of a plant to check on their health. He's grown cannabis most of his life and has traveled the world researching its many varieties. He's interested in developing new strains with higher concentrations of marijuana's lesser known compounds that appear to have medical uses. "Cannabis speaks to me," he says.

storemags.com





Marijuana grows in an irrigated field on the plains east of Denver — discreetly hidden behind rows of corn. This crop is hemp, a nonpsychoactive variety with little tetrahydrocannabinol (THC). Its tough fiber has long been used for rope, paper, and fabric, but it's also rich in compounds with medical promise. Some of this harvest will be used to make CBD oil, which is in such demand to treat children with seizures that cannabis growers have stepped up production.

By Hampton Sides

Photographs by Lynn Johnson

There's nothing new about cannabis, of course. It's been around humankind pretty much forever.

In Siberia charred seeds have been found inside burial mounds dating back to 3000 B.C. The Chinese were using cannabis as a medicine thousands of years ago. Marijuana is deeply American too—as American as George Washington, who grew hemp at Mount Vernon. For most of the country's history, cannabis was legal, commonly found in tinctures and extracts.

Then came Reefer Madness. Marijuana, the Assassin of Youth. The Killer Weed. The Gateway Drug. For nearly 70 years the plant went into hiding, and medical research largely stopped. In 1970 the federal government made it even harder to study marijuana, classifying it as a Schedule I drug—a dangerous substance with no valid medical purpose and a high potential for abuse, in the same category as heroin. In America most people expanding knowledge about cannabis were by definition criminals.

But now, as more and more people are turning to the drug to treat ailments, the science of

cannabis is experiencing a rebirth. We're finding surprises, and possibly miracles, concealed inside this once forbidden plant. Although marijuana is still classified as a Schedule I drug, Vivek Murthy, the U.S. surgeon general, recently expressed interest in what science will learn about marijuana, noting that preliminary data show that “for certain medical conditions and symptoms” it can be “helpful.”

In 23 states and the District of Columbia cannabis is legal for some medical uses, and a majority of Americans favor legalization for recreational use. Other countries are rethinking their relationship to pot too. Uruguay has voted to legalize it. Portugal has decriminalized it. Israel, Canada, and the Netherlands have medical marijuana programs, and in recent years numerous countries have liberalized possession laws.

Ganja is simply around us more, its unmistakable but increasingly unremarkable smell hanging in the air. Yes, smoking it may lead to

temporary laughing sickness, intense shoe-gazing, amnesia about what happened two seconds ago, and a ravenous yearning for Cheez Doodles. Though there's never been a death reported from an overdose, marijuana—especially today's stout iterations—is also a powerful and in some circumstances harmful drug.

Still, for many, cannabis has become a tonic to dull pain, aid sleep, stimulate appetite, buffer life's thumps and shocks. Pot's champions say it peels back layers of stress. It's also thought to be useful as, among other things, an analgesic, an antiemetic, a bronchodilator, and an anti-inflammatory. It's even been found to help cure a bad case of the hiccups. Compounds in the plant, some scientists contend, may help the body regulate vital functions—such as protecting the brain against trauma, boosting the immune system, and aiding in “memory extinction” after catastrophic events.

In the apparent rush to accept weed into the mainstream, to tax and regulate it, to legitimize and commodify it, important questions arise. What's going on inside this plant? How does marijuana really affect our bodies and our brains? What might the chemicals in it tell us about how our neurological systems function? Could those chemicals lead us to beneficial new pharmaceuticals?

If cannabis has something to tell us, what's it saying?

THE CHEMIST Treasure Trove

Even into the middle of the 20th century, science still didn't understand the first thing about marijuana. What was inside it and how it worked remained a mystery. Because of its illegality and tainted image, few serious scientists wanted to besmirch their reputations by studying it.

Then one day in 1963 a young organic chemist in Israel named Raphael Mechoulam, working at the Weizmann Institute of Science outside Tel Aviv, decided to peer into the plant's chemical composition. It struck him as odd that even though morphine had been teased from

opium in 1805 and cocaine from coca leaves in 1855, scientists had no idea what the principal psychoactive ingredient was in marijuana. “It was just a plant,” says Mechoulam, now 84. “It was a mess, ■ mélange of unidentified compounds.”

So Mechoulam called the Israeli national police and scored five kilos of confiscated Lebanese hashish. He and his research group isolated—and in some cases also synthesized—an array of substances, which he injected separately into rhesus monkeys. Only one had any observable effect. “Normally the rhesus monkey is quite an aggressive individual,” he says. But when injected with this compound, the monkeys became emphatically calm. “Sedated, I would say,” he recalls with a chuckle.

Further testing found what the world now knows: This compound is the plant's principal active ingredient, its mind-altering essence—the stuff that makes you high. Mechoulam, along with a colleague, had discovered tetrahydrocannabinol (THC). He and his team also elucidated the chemical structure of cannabidiol (CBD), another key ingredient in marijuana, one that has many potential medical uses but no psychoactive effect on humans.

For these breakthroughs and many others, Mechoulam is widely known as the patriarch of cannabis science. Born in Bulgaria, he is a decorous man with wispy white hair and watery eyes who wears natty tweeds, silk scarves, and crisp dress slacks. He's a respected member of the Israel Academy of Sciences and Humanities and an emeritus professor at Hebrew University's Hadassah Medical School, where he still runs a lab. The author of more than 400 scientific papers and the holder of about 25 patents, this kindly grandfather has spent a lifetime studying cannabis, which he calls a “medicinal treasure trove waiting to be discovered.” His work has spawned a subculture of cannabis research around the globe. Though he says he's never smoked the stuff, he's a celebrity in the pot world and receives prodigious amounts of fan mail.

“It's all your fault,” I say to him when we meet in his book-lined, award-crammed office

to discuss the explosion of interest in the science of marijuana.

“Mea culpa!” he replies with a smile.

Israel has one of the world’s most advanced medical marijuana programs. Mechoulam played an active role in setting it up, and he’s proud of the results. More than 20,000 patients have a license to use cannabis to treat such conditions as glaucoma, Crohn’s disease, inflammation, appetite loss, Tourette’s syndrome, and asthma.

Despite that, he’s not particularly in favor of legalizing cannabis for recreational use. He doesn’t think anyone should go to jail for possessing it, but he insists that marijuana is “not an innocuous substance”—especially for young people. He cites studies showing that the prolonged use of high-THC strains of marijuana can change the way the developing brain grows. He notes that in some people cannabis can provoke serious and debilitating anxiety attacks. And he points to studies that suggest cannabis may trigger the onset of schizophrenia among those who have a genetic predisposition to the disease.

If he had his way, what Mechoulam regards as the often irresponsible silliness of recreational pot culture would give way to an earnest and enthusiastic embrace of cannabis—but only as a medical substance to be strictly regulated and relentlessly researched. “Right now,” he complains, “people don’t know what they’re getting. For it to work in the medical world, it has to be quantitative. If you can’t count it, it’s not science.”

In 1992 Mechoulam’s quest for quantification led him from the plant itself to the inner recesses of the human brain. That year he and several colleagues made an extraordinary discovery. They isolated the chemical made by the human body that binds to the same receptor in the brain that THC does. Mechoulam named it anandamide—from the Sanskrit for “supreme

joy.” (When asked why he didn’t give it a Hebrew name, he replies, “Because in Hebrew there are not so many words for happiness. Jews don’t like being happy.”)

Since then several other so-called endocannabinoids and their receptors have been discovered. Scientists have come to recognize that endocannabinoids interact with a specific neurological network—much the way that endorphins, serotonin, and dopamine do. Exercise, Mechoulam notes, has been shown to elevate endocannabinoid levels in the brain, and “this probably accounts for what jogging enthusiasts call runner’s high.” These compounds, he explains, apparently play an important role in such basic functions as memory, balance, movement, immune health, and neuroprotection.

Typically, pharmaceutical companies making cannabis-based medicines have sought to isolate individual compounds from the plant. But Mechoulam strongly suspects that in some cases those chemicals would work much better in concert with other compounds found in marijuana. He calls this the entourage effect, and it’s just one of the many cannabis mysteries that he says require further study.

“We have just scratched the surface,” he says, “and I greatly regret that I don’t have another lifetime to devote to this field, for we may well discover that cannabinoids are involved in some way in all human diseases.”

THE BOTANIST

Into the Light

The 44,000-square-foot building hulks across from a police station in an industrial part of Denver, along a gritty stretch of converted warehouses that’s come to be known as the Green Mile. There’s nothing to indicate the nature of the enterprise. The door buzzes open, and I’m met by the chief horticulturist of Mindful, one of the largest cannabis companies in the world. A druidlike 38-year-old with keen blue eyes, Phillip Hague wears fatigues, hiking boots, and the incredulous grin of someone who—through a confluence of events he never imagined

Hampton Sides, author of In the Kingdom of Ice and other histories, wrote about Russia’s Wrangel Island in May 2013. Lynn Johnson has photographed 23 stories for the magazine; her last was “Healing Soldiers” in February.



Cash is the norm for many cannabis businesses, even in Colorado, because banks are reluctant to handle money from marijuana-related sales. Jayson "Giddy Up" Emo, who runs a Denver firm that makes machines for extracting chemicals from cannabis, protects his proceeds the old-fashioned way—with firepower.

possible—has found his exact life's calling.

Hague is a self-described plantsman, a dirty-thumbed gardener since he was eight and a devotee of the great agricultural scientist Luther Burbank. For years Hague grew poinsettias, caladiums, chrysanthemums, and other plants in his family's nursery in Texas. But now his attentions are lavished on much more lucrative buds.

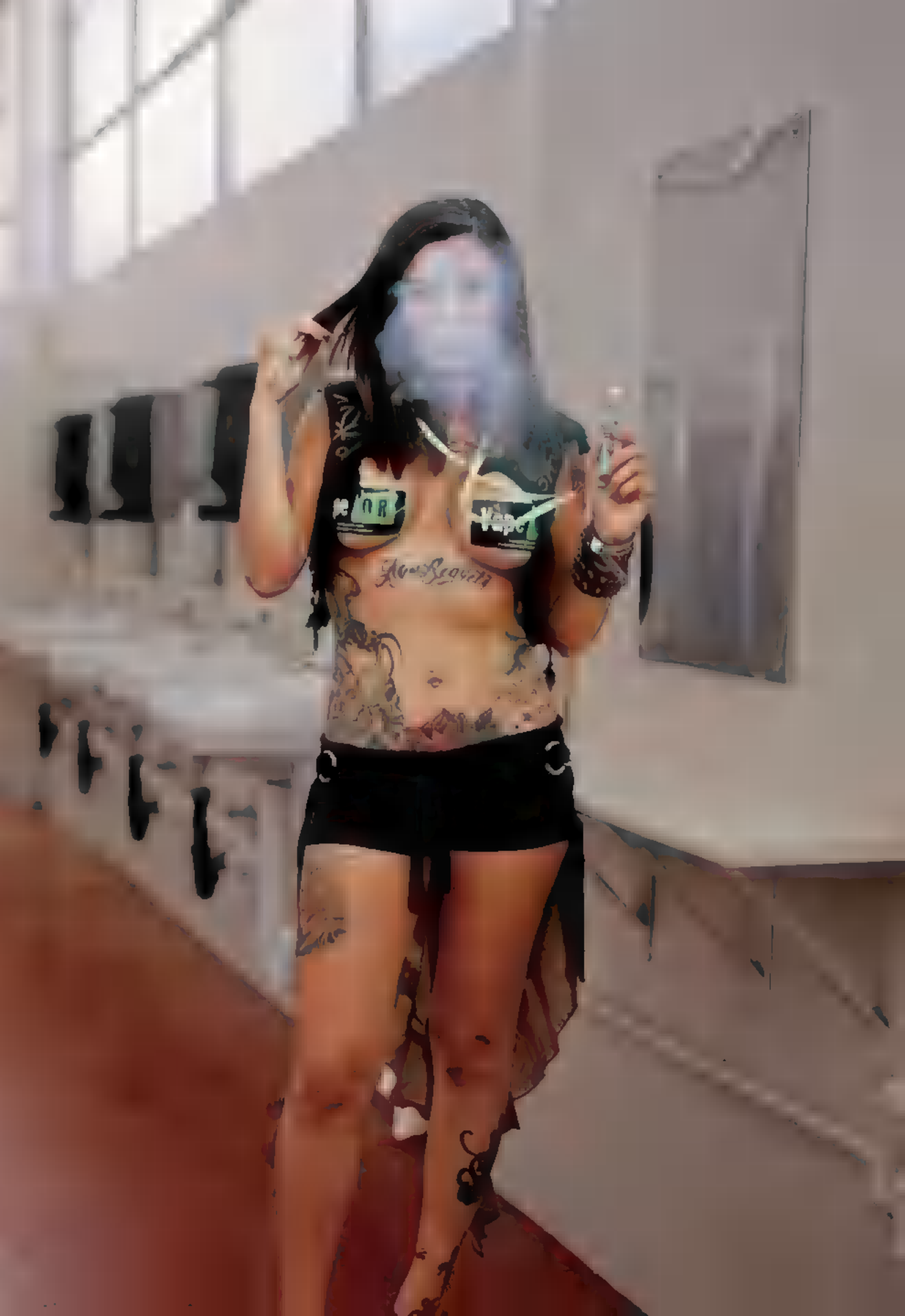
He leads me through Mindful's bustling front offices and into its interior corridors. In freezers Mindful stores seeds from all over—Asia, India, North Africa, the Caribbean. A world traveler who's become something of a Johnny Appleseed

for marijuana, Hague is extremely interested in the plant's historical biodiversity, and his seed bank of rare, wild, and ancient strains is a significant part of Mindful's intellectual property. "We have to recognize that humans evolved with it practically since the dawn of time," he says. "It's older than writing. Cannabis use is part of us, and it always has been. It spread from Central Asia after the last ice age and went out across the planet with man."

Hague joined Colorado's green revolution nearly at the beginning. When the U.S. Justice Department announced *(Continued on page 48)*

At a cannabis competition in Santa Rosa, California, ■ young enthusiast becomes a human billboard for a company that sells devices to vaporize the drug. California allows marijuana for medical but not recreational use. As "ganjapreneurs" seek to capitalize on the legalization movement, the paraphernalia industry has expanded dramatically, employing a sleek aesthetic—and a certain sex appeal—to market products once confined to head shops.





Marijuana's Moment

More than 20 million Americans used marijuana in 2013. Possession and sale are illegal under federal law, but medical use is legal in 23 states and the District of Columbia. Many states also have reduced or eliminated penalties for recreational use, resulting in a patchwork of restrictions and availability for those seeking medical help or just a casual high.

Medical

Cannabis was a mainstay of healers in ancient China, India, and Greece. Today its status as an illegal drug under federal law hampers scientists who want to study its medical potential. Only two synthetic medicines have been approved by the Food and Drug Administration; a natural derivative is under review.

GLAUCOMA

Researchers are developing a drug that mimics marijuana's ability to reduce pressure in the eye but without the plant's side effects.

MULTIPLE SCLEROSIS

An extract that relieves pain and muscle spasms in MS patients has been approved in Europe and Canada, though not in the U.S.

AIDS

One of the FDA-approved synthetic versions of a substance found in marijuana helps increase appetite and treat weight loss in patients with the disease.

CANCER

The other synthetic version is used to treat nausea associated with chemotherapy.



Recreational

The primary psychoactive chemical in marijuana, tetrahydrocannabinol, or THC, acts on the brain to produce the high recreational users crave. Colors, sounds, and skin sensations can intensify, and time may seem to slow. Cannabis can also worsen the symptoms of depression and anxiety.

BRAIN

Many parts of the brain have receptors that react to marijuana. Some regulate food intake and cause cravings. Others regulate dopamine and can cause a sense of euphoria.

RESPIRATORY SYSTEM

Effects are felt seconds after inhalation and peak within 30 minutes. Unfiltered cannabis, inhaled deeply, can expose smokers to more carbon monoxide and tar than cigarettes do.

HEART

Heart rate can double, prompting panic attacks in some users. Studies also show that shortly after use, the risk of a heart attack can increase significantly.

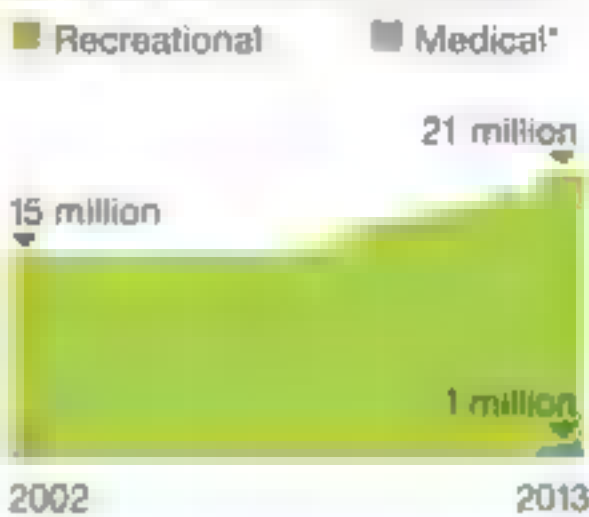
DIGESTIVE SYSTEM

When cannabis is eaten, its effects kick in more slowly and last longer, making it hard to regulate dosage. Feelings of hunger often intensify.

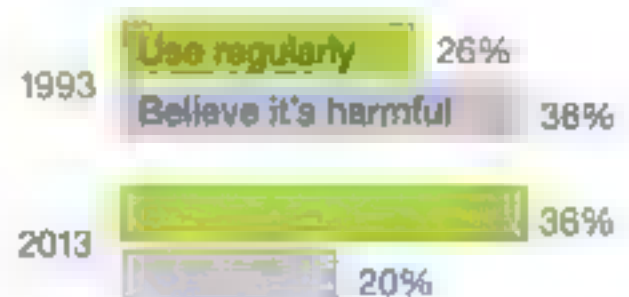
Marijuana is rising in popularity...

Recreational users outnumber medical users. Despite the risk to their developing brains, a third of teens say they've used marijuana in the past month.

U.S. marijuana use, 12 and older



U.S. teen marijuana use versus teen perception of harm



and increasingly available in U.S. states...

As states loosen restrictions, one politically appealing option is cannabidiol (CBD) oil, which has some of marijuana's health effects without the high.

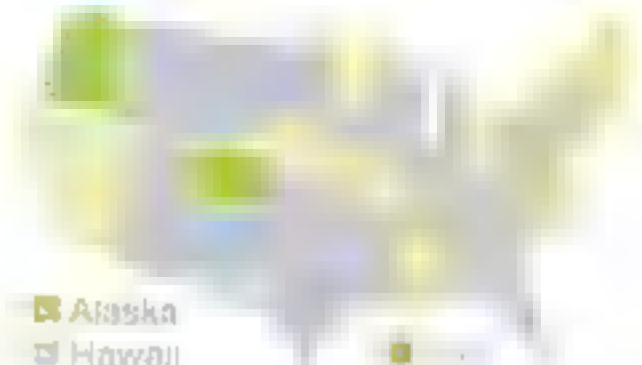
States where medical marijuana is legal

■ All forms ■ CBD oil only



States where recreational marijuana laws have changed

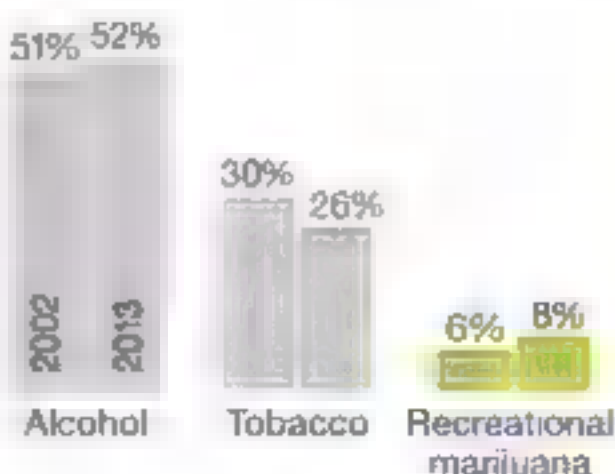
■ Legal** ■ Decriminalized*



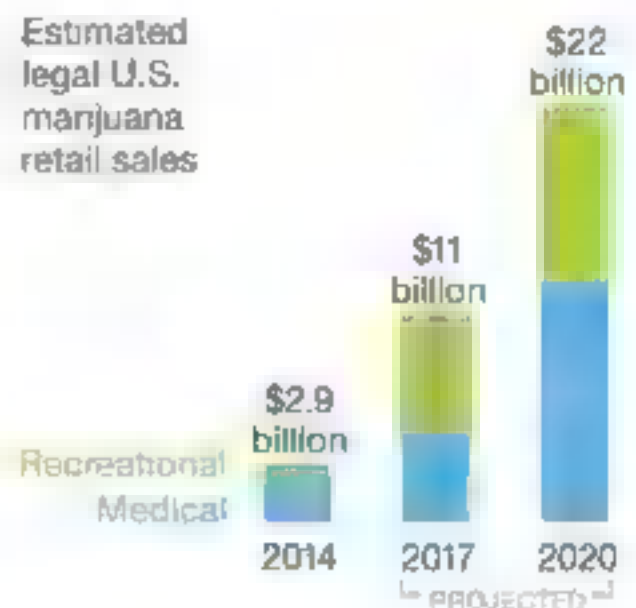
creating a lucrative new market.

Illicit marijuana use is dwarfed by the use of other substances. As demand for legal marijuana grows, businesses are eyeing this new market.

Change in use, share of U.S. population



Estimated legal U.S. marijuana retail sales



*2002-13 DATA NOT AVAILABLE **IN OREGON AS OF JULY 1, 2015 *TREATED LIKE A MINOR TRAFFIC VIOLATION
 JOHN TOMANIO, NGM STAFF; SHELLEY SPERRY, ART; BRYAN CHRISTIE, DESIGN; SOURCES: GREENWAVE ADVISORS, MARIJUANA POLICY PROJECT; MONITORING THE FUTURE SURVEY, 2013; NATIONAL SURVEY ON DRUG USE AND HEALTH, IGOR GRANT, UNIVERSITY OF CALIFORNIA, SAN DIEGO; NATIONAL CONFERENCE OF STATE LEGISLATURES





At Denver's LivWell, which has an enormous indoor growing operation, workers remove marijuana leaves before the buds are trimmed, keeping the plants destined for medical use separate from those for recreational use. After Colorado legalized marijuana, thousands of young people from all over the world flocked to the state to participate in the multimillion-dollar business phenomenon that's been called the Green Rush.



In northern California, Nicholas and Richard Lopez take photographs of their harvest to share online. Recovering meth addicts who've served time for drug offenses, the brothers say they've turned over a new leaf. They proudly tend a small garden of pot, which they use to cope with bouts of anxiety caused by years of meth abuse.

in 2009 that it would not focus on prosecuting people who complied with state medical marijuana laws, he looked at his wife and said, "We're moving to Denver." Now he runs one of the world's most prominent "grows," where more than 20,000 cannabis plants thrive.

We file past the curing rooms and down a hallway pulsating with pumps, fans, filters, generators, trimming machines. A forklift trundles by. Surveillance cameras capture everything, as young workers in medical scrubs scurry about, their faces lit with the pressure and promise of an unorthodox business that's boomed beyond

comprehension. Mindful has big plans to expand, building similar facilities in other states. "Pot is hot!" Hague says with a laugh that conveys amazement and exhaustion. "I'm blown away by what's happening here every single day."

He throws open an industrial door, and my eyeballs are scalded by a halo of plasma bulbs. We step into an immense, warm room that smells like a hundred Yes concerts. Once my eyes adjust, I can see the crop in all its rippling glory—close to a thousand female plants standing six feet tall, their roots bathed in a soup of nutrients, their spiky leaves nodding in the

breeze of the oscillating fans. Here in a sweep of the eye is more than a half million dollars' worth of artisanal pot.

I lean over to sniff one of the powdery, tightly clustered flower buds, purple-brown and coursing with white wisps. These tiny trichomes fairly ooze with cannabinoid-rich resin. This strain is called Highway Man, after a Willie Nelson song. Hybridized by Hague, it's a variety loaded with THC. The best parts will be trimmed by hand, dried, cured, and packaged for sale at one of Mindful's dispensaries. "This whole room will be ready for harvest in just a few days," Hague notes with the subtle smirk of a competitive breeder who's won international awards for his strains.

But Hague has something else he wants to show me. He leads me into a moist propagation room, where a young crop is taking root in near darkness. These babies, tagged with yellow labels, are being grown strictly for medical purposes. They're all clones, cuttings from a mother plant. Hague is proud of this variety, which contains almost no THC but is rich in CBD and other compounds that have shown at least anecdotal promise in treating such diseases and disorders as multiple sclerosis, psoriasis, post-traumatic stress disorder, dementia, schizophrenia, osteoporosis, and amyotrophic lateral sclerosis (Lou Gehrig's disease).

"It's these low-THC strains that really keep me up at night, dreaming about what they can do," Hague says, noting that marijuana contains numerous substances—cannabinoids, flavonoids, terpenes—that have never been investigated in depth.

"It sounds hokey," he says as he caresses one of the cuttings like a gloating father, "but I believe cannabis has a consciousness. It's tired of being persecuted. It's ready to step out into the light."

THE BIOCHEMIST Miracle Cure?

By now nearly everyone has heard that cannabis can play a palliative role for cancer sufferers, especially in alleviating some of the nasty side

effects of chemotherapy. There's no question that pot can stave off nausea, improve appetite, and help with pain and sleep. But could it cure cancer? Troll the Internet and you'll see hundreds, if not thousands, of such claims. A gullible Googler could easily believe we're on the brink of a miracle cure.

The majority of these claims are anecdotal at best and fraudulent at worst. But there are also mentions of laboratory evidence pointing to cannabinoids as possible anticancer agents, and many of these reports lead to a lab in Spain run by a thoughtful, circumspect man named Manuel Guzmán.

Guzmán is a biochemist who's studied cannabis for about 20 years. I visit him in his office at the Complutense University of Madrid, in a golden, graffiti-splotched building on a tree-lined boulevard. A handsome guy in his early 50s with blue eyes and shaggy brown hair tinged with gray, he speaks rapidly in a soft voice that makes a listener lean forward. "When the headline of a newspaper screams, 'Brain Cancer Is Beaten With Cannabis!' it is not true," he says. "There are many claims on the Internet, but they are very, very weak."

He blinks thoughtfully, then turns to his computer. "However, let me show you something." On his screen flash two MRIs of a rat's brain. The animal has a large mass lodged in the right hemisphere, caused by human brain tumor cells Guzmán's researchers injected. He zooms in. The mass bulges hideously. The rat, I think, is a goner. "This particular animal was treated with THC for one week," Guzmán continues. "And this is what happened afterward." The two images that now fill his screen are normal. The mass has not only shrunk—it's disappeared. "As you can see, no tumor at all."

In this study Guzmán and his colleagues, who've been treating cancer-riddled animals with cannabis compounds for 15 years, found that the tumors in a third of the rats were eradicated and in another third, reduced.

This is the kind of finding that gets the world excited, and Guzmán constantly worries that his breakthrough research may give cancer



sufferers false hope—and fuel specious Internet claims. “The problem is,” he says, “mice are not humans. We do not know if this can be extrapolated to humans at all.”

Guzmán leads me around his cramped lab—centrifuges, microscopes, beakers, petri dishes, a postdoc researcher in a white smock extracting tissue from a mouse corpse pinned under bright lights. It’s your typical bioresearch lab, except that everything is devoted to the effects of cannabis on the body and brain. The lab focuses not just on cancer but also on neurodegenerative diseases and on how cannabinoids affect early brain development. On this last topic the Guzmán group’s research is unequivocal: Mice born of mothers regularly given high doses of THC during pregnancy show pronounced problems.

They’re uncoordinated, have difficulty with social interactions, and have a low anxiety threshold—they’re often paralyzed with fear at stimuli, such as a cat puppet placed near their cage, that don’t upset other juvenile mice.

The lab also has studied how the chemicals in cannabis, as well as cannabinoids like the anandamide produced by our bodies, protect our brains against various types of insults, such as physical and emotional trauma. “Our brain needs to remember things, of course,” says Guzmán, “but it also needs to forget things—horrible things, unnecessary things. It’s much like the memory in your computer—you have to forget what is not necessary, just like you need to periodically delete old files. And you have to forget what is not good for your mental health—a war,



Helped by her granddaughters, Mari Schwarting (opposite) prepares soil for a family business that makes cannabis-based creams and salves in Washington State, which has legalized the drug. Members of a Seattle cannabis business association called Women of Weed (above) gather to share trade secrets—and intoxicating talk.

a trauma, an aversive memory of some kind. The cannabinoid system is crucial in helping us push bad memories away.”

But it’s Guzmán’s brain tumor research that has captured headlines—and the interest of pharmaceutical companies. Through his years of research he has ascertained that a combination of THC, CBD, and temozolomide (a moderately successful conventional drug) works best in treating brain tumors in mice. A cocktail composed of these three compounds appears to attack brain cancer cells in multiple ways, preventing their spread but also triggering them,

in effect, to commit suicide.

Now a groundbreaking clinical trial based on Guzmán’s work is under way at St. James’s University Hospital, in Leeds, England. Neuro-oncologists are treating patients who have aggressive brain tumors with temozolomide and Sativex, a THC-CBD oral spray developed by GW Pharmaceuticals.

Guzmán cautions against overoptimism but welcomes the beginning of human studies. “We have to be objective,” he says. “At least the mindset is opening around the world, and funding agencies now know that cannabis, as a drug, is



KAMAKAZI
OG 10g

KING BUBBA
OG 10
INDICA

POISON
OG 10g
INDICA



At Noho's Finest, a medical marijuana dispensary in the Los Angeles area, Damaris Diaz checks the scent and stickiness of her products. Crossbreeding has yielded powerful new hybrid strains that are much higher in psychoactive THC than those in decades past—a source of concern for health officials, who cite evidence that the prolonged smoking of high-THC varieties can adversely affect the developing brain.

tags

“If they were growing something on Mars that might help

scientifically serious, therapeutically promising, and clinically relevant.”

Will cannabis help fight cancer? “I have a gut feeling,” he says, “that this is real.”

THE CAREGIVER

Medical Migrants

The seizures started in May 2013 when she was six months old. Infantile spasms, they were called. It looked like a startle reflex—her arms rigid at her side, her face a frozen mask of fear, her eyes fluttering from side to side. Adelyn Patrick’s little brain raced and surged, as though an electromagnetic storm were sweeping through it. “It’s your worst possible nightmare,” her mother, Meagan, says. “Just awful, awful, awful to watch your child in pain, in fear, and there’s nothing you can do to stop it.”

From their small town in southwestern Maine, Meagan and her husband, Ken, took Addy to Boston to consult with neurologists. These epileptic seizures, they concluded, were the result of a congenital brain malformation called schizencephaly. One of the hemispheres of Addy’s brain had not developed fully in utero, leaving an abnormal cleft. She also had a related condition called optic nerve hypoplasia, which caused her eyes to wander—and which, further tests revealed, made her all but blind. By summer Addy was having 20 to 30 seizures a day. Then 100 a day. Then 300. “Everything was misfiring all at once,” says Meagan. “We were afraid we were going to lose her.”

The Patricks followed the advice they’d been given and heavily medicated Addy with anti-convulsants. The powerful meds reduced her seizures, but they also put her to sleep for almost the entire day. “Addy was gone,” Meagan says. “She just lay there, sleeping all the time. Like a rag doll.”

Meagan quit her job as a third-grade teacher to care for her daughter. Over nine months Addy was hospitalized 20 times.

When Meagan’s in-laws suggested they look into medical marijuana, she recoiled. “This is a federally illegal drug we are talking about,” she

recalls thinking. But she did her own research. A good deal of anecdotal evidence shows that high-CBD strains of cannabis can have a strong antiseizure effect. The medical literature, though scant, goes back surprisingly far. In 1843 a British doctor named William O’Shaughnessy published an article detailing how cannabis oil had arrested an infant’s relentless convulsions.

In September 2013 the Patricks met with Elizabeth Thiele, a pediatric neurologist at Boston’s Massachusetts General Hospital who’s helping lead a study of CBD in treating refractory childhood epilepsy. Legally, Thiele could not prescribe cannabis to Addy or even recommend it. But she strongly advised the Patricks to consider all medical options.

Encouraged, Meagan went to Colorado and met with parents whose epileptic children were taking a strain of cannabis called Charlotte’s Web, named for a little girl, Charlotte Figi, who’d responded astonishingly well to the low-THC, high-CBD oil produced near Colorado Springs.

What Meagan saw in Colorado impressed her—the growing knowledge base of cannabis producers, the kinship of parents coping with similar ordeals, the quality of the dispensaries, and the expertise of the test labs in ensuring consistent cannabis-oil formulations. Colorado Springs had become a mecca for a remarkable medical migration. More than a hundred families with children who had life-threatening medical conditions had uprooted themselves and moved. These families, many of them associated with a nonprofit organization called the Realm of Caring, consider themselves “medical refugees.” Most couldn’t medicate their children with cannabis in their home states without risking arrest for trafficking or even child abuse.

Meagan experimented with high-CBD oil. The seizures all but stopped. She weaned Addy off some of her other meds, and it was as though she’d come back from a coma. “It sounds like a small thing,” says Meagan. “But if you have a child who smiles for the first time in many, many months, well, your whole world changes.”

By early last year the Patricks had made up

Addy, I'd be in my backyard building a spaceship."

—Meagan Patrick, Addy's mother

their minds. They would move to Colorado to join the movement. "It was a no-brainer," Meagan says. "If they were growing something on Mars that might help Addy, I'd be in my backyard building a spaceship."

When I meet the Patricks in late 2014, they've settled into their new home on the north side of Colorado Springs. Pikes Peak looms in their living room window. Addy is thriving. Since first taking CBD oil, she hasn't been hospitalized. She still has occasional seizures—one or two a day—but they're less intense. Her eyes wander less. She listens more. She laughs. She's learned how to hug and has discovered the power of her vocal cords.

Critics contend that the Realm of Caring parents are using their kids as guinea pigs, that not enough studies have been done, that many, if not most, of the claims can be dismissed as the result of the placebo effect. "It's true, we don't know the long-term effects of CBD, and we should study it," Meagan says. "But I can tell you this. Without it, our Addy would be a sack of potatoes." No one asks, she notes, about the long-term effects of a widely used pharmaceutical that has been routinely prescribed for her two-year-old. "Our insurance pays for it, no questions asked," she says. "But it's highly addictive, highly toxic, turns you into a zombie, and can actually kill you. And yet it's perfectly legal."

Thiele says early results of the CBD study are extremely encouraging. "CBD is not a silver bullet—it doesn't work for everybody," she cautions. "But I'm impressed. It clearly can be a very effective treatment for many people. I have several kids in the study who've been completely seizure free for over a year."

Reports like these only deepen Meagan's frustrations with what she has come to regard as the imbecility of federal marijuana laws that put her at risk of arrest for transporting a drug that "wouldn't get a mouse high" across state lines. "It's unacceptable," she says, "that we're allowing our citizens to suffer like this."

But the Patricks are in a good place now—happier than they've been in years. "We have Addy back again," Meagan says. "If I wasn't

living through this, I don't know that I'd believe it myself. I don't feel like cannabis is a miracle cure. But I feel like it should be a tool in every neurologist's toolbox, all around the country."

THE GENETICIST

Building the Map

"It's such an interesting plant, such a valuable plant," says Nolan Kane, who specializes in evolutionary biology. "It's been around for millions of years, and it's one of man's oldest crops. And yet there are so many basic problems that need to be answered. Where did it come from? How and why did it evolve? Why does it make all these suites of compounds? We don't even know how many species there are."

We're standing in a laboratory greenhouse on the campus of the University of Colorado Boulder looking at ten hemp plants that Kane recently procured for research purposes. They're spindly, stinky little things, like gangling teenagers, a far cry from the lascivious crop that Hague had shown me. These plants, like nearly all hemp varieties, carry extremely low levels of THC.

They may not look threatening, but their very presence here, in the confines of a major university lab, represents years of wrangling to win federal and university approval. Right now, Kane's allowed to grow only hemp strains. The rest of his research material is cannabis DNA, which is supplied by Colorado growers who extract it using methods he's taught them.

Kane fingers one of his innocuous-looking plants, expressing mild bemusement at the U.S. ban on commercial hemp cultivation. "Hemp produces fibers of unparalleled quality," he notes.

▶ MORE ONLINE

ngm.com/more

VIDEO

Cannabis for Kids: A Growing Debate

After exhausting all other options, some parents are looking to medical marijuana to help their sick children. Follow their stories—and struggles—in this short film.



SPENCER MILLGAP/NGM STAFF



"It's a tremendously high biomass crop that replenishes the soil and doesn't require much in terms of inputs. We import tons and tons of hemp each year from China and even Canada, yet as a matter of federal policy, we can't legally grow it. There are places where farmers in the U.S. can literally look across the Canadian border and see fields that are yielding huge profits."

A geneticist, Kane studies cannabis from a unique perspective—he probes its DNA. He's an affable, outdoorsy guy with a bright face and eyes that wander and dart inquisitively when he talks. He has studied chocolate and for many years the sunflower, eventually mapping its genome, a sequence of more than three and a half billion nucleotides. Now he's moved on to marijuana. Though its sequence is much shorter,

roughly 800 million nucleotides, he considers it a far more intriguing plant.

A sketchy outline of the cannabis genome already exists, but it's highly fragmented, scattered into about 60,000 pieces. Kane's ambitious goal, which will take many years to achieve, is to assemble those fragments in the right order. "The analogy I use is, we have 60,000 pages of what promises to be an excellent book, but they're strewn all over the floor," he says. "We have no idea yet how those pages fit together to make a good story."

Many people are more than a little eager to learn how Kane's story will play out. "There's a certain pressure," he says, "because this work will have huge implications, and anything we do in this lab will be under a lot of scrutiny. You can feel it. People are just wanting this to happen."



Kim Clark (opposite) says CBD oil has worked wonders for her epileptic 11-year-old son, Caden. Orrin Devinsky (above), a neurologist at New York University, is more skeptical. He's leading a clinical trial to test CBD against a placebo in treating forms of epilepsy. "There's real potential," he says, "but we urgently need valid data."

Once the map is complete, enterprising geneticists will be able to use it in myriad ways, such as breeding strains that contain much higher levels of one of the plant's rare compounds with medically important properties. "It's like discovering some hidden motif deep in a piece of music," Kane says. "Through remixing, you can accentuate it and turn it up so that it becomes a prominent feature of the song."

As Kane leads me around his lab, I see the excitement on his face and on the faces of his young staff. The place feels almost like a start-up company. "So much of science is incremental," he

says, "but with this cannabis work, the science will not be incremental. It will be transformative. Transformative not just in our understanding of the plant but also of ourselves—our brains, our neurology, our psychology. Transformative in terms of the biochemistry of its compounds. Transformative in terms of its impact across several different industries, including medicine, agriculture, and biofuels. It may even transform part of our diet—hemp seed is known to be a ready source of a very healthy, protein-rich oil."

Cannabis, Kane says, "is an embarrassment of riches." □



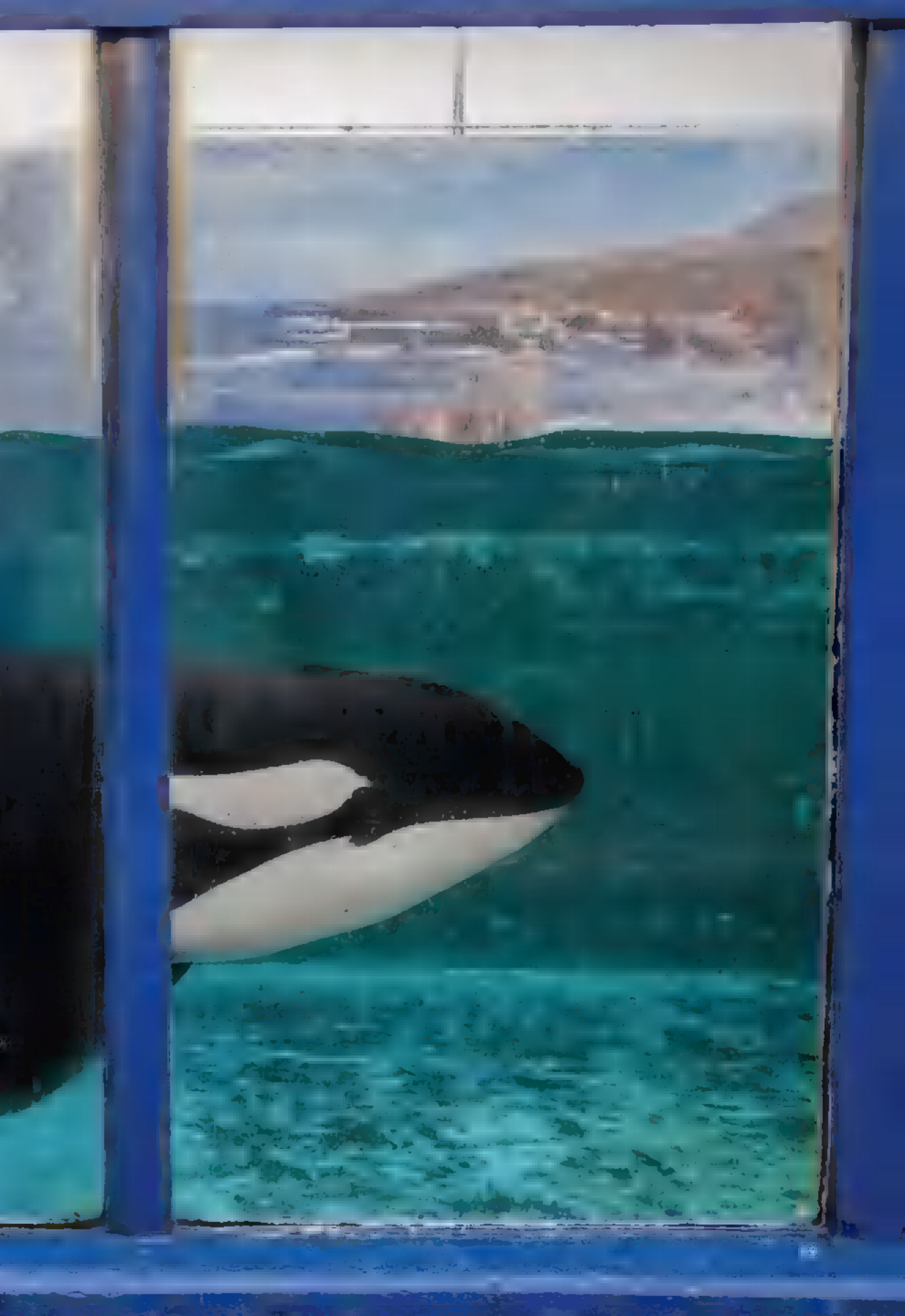
BORN *to be* WILD

Thousands of dolphins have been taken captive to perform in shows at marine parks. Now some are being taught how to go home again.

MORGAN *Netherlands*

Picked up off the Dutch coast, this female orca was sent to Spain after officials worried she wouldn't survive a return to the wild. Orcas, or killer whales, are the largest dolphins.

MARTEN VAN OUL / AFP/GETTY IMAGES





CHUNSAM *South Korea*

Easily identified by the "2" marked on her dorsal fin, Chunsam swims in the waters off Jeju Island. After seven years in captivity, the released dolphin quickly returned to her native pod, improving her chances of readapting to the wild.

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By Tim Zimmermann

**UNDERSTANDING
DOLPHINS**

INTELLIGENCE



CAPTIVITY

CULTURE

a three-part series



n early January 2011 Jeff Foster, a 55-year-old marine mammal expert from Seattle, arrived on the stony shore of a pristine bay near the small village of Karaca, situated in a corner of the Gulf of Gökova on Turkey's southwest coast. Just offshore was a collection of floating pens used to farm fish. In one of them, which had been modified and measured about a hundred feet across and 50 feet deep, two male bottlenose dolphins swam in slow circles.

Tom and Misha, as they were called, were in lamentable condition. As far as anyone could tell, they'd been captured in the Aegean sometime in 2006, and almost nothing was known about their lives in the wild. After starting their captive lives at a dolphin park in the seaside town of Kaş, they'd been trucked a short distance inland in June 2010 to a crudely constructed concrete pool in the mountain town of Hisarönü so that tourists could pay \$50 for the chance to grab their dorsal fins and get a ten-minute tow. Hisarönü consists mainly of cheap hotels and bars with suggestive names like Oh Yes! and thumping late-night music. It would be hard to imagine a more incongruous or disorienting location for two ocean-born dolphins. An inadequate filtration system quickly left the bottom of their pool carpeted with dead fish and dolphin feces.

Within weeks, an outraged grassroots and social media campaign organized by dolphin-loving locals had forced the place to close. In early September, amid fears that the dolphins

would soon die, the U.K.-based Born Free Foundation, which is dedicated to the protection of animals in the wild, stepped in and took possession of Tom and Misha. The two dolphins were bundled into a refrigerated meat truck lined with old mattresses and transported to the pen off Karaca. Foster was hired to help Born Free attempt something truly ambitious: restore Tom and Misha to peak physical condition, teach them what they would need to know to live as wild dolphins again, and release them back into the Aegean. "It is extremely high risk with a creature that is not predictable and easy," says Will Travers, Born Free's president. "But we realized that there were very few options for them, and they were likely to die unless somebody did something."

Questions about the ethics of keeping dolphins in captivity, especially for public entertainment, have intensified as their intellectual and cognitive abilities become better understood. Dolphins are among the most intelligent species on the planet: self-aware, highly social,



DOM AND MISHA *Turkey*

Dom and Misha swim in their net pen on the Aegean coast.

Captive dolphins become so accustomed to eating dead fish from a trainer's hand that they don't consider live fish food. Trainers must teach them how to hunt again before they can be released.

100/100000

with brains that are notably large and complex for their body size. They're capable of extensive communications and use signature whistles that are analogous to individual names. They can recognize themselves in a mirror and understand abstract concepts, and they've demonstrated a grasp of grammar and syntax.

Fewer than three dozen long-term captive dolphins had been released over the previous

the United States as well as Iceland. In addition to killer whales, he took smaller dolphins, sea lions, seals, and other animals from the wild for captive display.

Though Foster tried not to wrestle too much with the question of whether Tom and Misha were helping him pay a karmic debt, the work felt right. He had caught his first killer whale because it was a far more interesting way to earn

Tom and Misha, in captivity since 2006, offered an opportunity to elevate the art and science of **teaching a dolphin to be wild again.**

50 years, with mixed and often inconclusive results. Tom and Misha offered an opportunity to elevate the art and science of teaching a dolphin to be wild again and better define at least one alternative to continued captivity. "This is the sort of thing that touches people to the core," says Travers. "If we could get it right for Tom and Misha, it could inspire people and help people move along to question [captive dolphin] display."

If Tom and Misha offered Born Free a chance to define the future, they offered Jeff Foster a chance at partial redemption. Foster has long blond hair, an easygoing manner, and the ruddy complexion of a man who's severely allergic to office cubicles. The son of a Seattle veterinarian, he has always loved learning about animals and went to work for the Seattle Marine Aquarium at the age of 15. Starting in 1976, when he was 20, he helped Don Goldsberry, who became SeaWorld's most prolific collector of marine mammals, set up an operation to catch orcas, or killer whales—the largest species of dolphin—in Iceland. Over the next 14 years Foster helped capture some two dozen killer whales for SeaWorld and other marine parks from waters off

a living than flipping burgers, and he sincerely thought it was the best way to learn about a little-understood animal. But listening to the plaintive cries of young animals alone and confined on the deck of a capture boat taught him that the moral calculation was complex. He did his best to use his hands and voice to calm fearful and distressed young killer whales, and he refused to follow the practices of those who believed that withholding food would help break a killer whale and make it more submissive. Still, he says, "the more you do it, the more you realize you are separating families. You can't feel good about taking something from the wild."

Ironically Foster's extensive experience bringing dolphins into captivity meant he was uniquely qualified to reverse the process. It also made him an awkward partner for Born Free. "Jeff was very much from the capture industry, and we were very nervous," says Alison Hood, who supervised the project for Born Free. "But he is an absolute wealth of knowledge, and we had taken responsibility for Tom and Misha and had a responsibility to give them the best chance, no matter what." Foster thought the process of rehabilitating Tom and Misha and preparing them for release might take six to eight months and cost \$500,000—for the pen, the staff, the equipment, the live fish. Born Free hoped it would

*Tim Zimmermann has written extensively about the captive dolphin and killer whale industry. He was associate producer of the documentary film **Blackfish**.*

cost less than half that. They were both wrong.

Helping wild-caught dolphins return to the natural world they once knew so well is not as simple as it might seem. A captive dolphin has the same anatomy and DNA it had in the wild, but it is in many ways a different animal. A wild dolphin lives a life of unpredictability and competition. It socializes and hunts across a vast expanse, moving almost constantly, encountering a multitude of species and new situations. Apart from surfacing to breathe, a wild dolphin spends most of its life underwater.

The marine park experience is the wild inverted. The physical space is tightly constricted and relatively barren, life is on a schedule, and there's no need to hunt and forage. Outside of training and shows, there's also little need for movement. Most notably, a captive dolphin's orientation changes profoundly: The world above the surface suddenly becomes much more

important than the world below. Almost all the action—from feedings to training sessions to audiences applauding to the directions given during shows—is topside. One simple comparison makes the point. Wild dolphins spend an estimated 80 percent of their time well below the surface. Captive dolphins spend about 80 percent of their time at or near the surface.

Foster caught his last killer whale for captivity in 1990, though he continued to capture other dolphins and sea lions. But he'd also started devoting more time to wild whale research and from 1996 to 2001 was heavily involved in the attempt to return Keiko, the killer whale star of *Free Willy*, to its native Icelandic waters. (Keiko swam free in 2002 but died of pneumonia in 2003.) Foster moved from that controversial experiment to the successful 2002 rehabilitation and release back to her pod of a young female killer whale called Springer that had been

Lead trainer Jeff Foster sends Tom and Misha on a high-energy training run. Captive dolphins get out of shape. Instead of hunting and swimming underwater, they spend almost all of their time at or near the surface.

2 DERVA YILDIRIM



TOM AND MISHA *Turkey*

Tom and Misha separated soon after their release into the Aegean. When Tom was threatened by fishermen, he had to be relocated—but he fought recapture. “The look in his eye was that of a totally wild animal,” says one of Foster’s assistants. “It was cool.”

JEFF FOSTER





found alone and malnourished off the coast of Washington State. “The captive industry thinks I am freeing animals and is very leery of some of the work we have done. I am kind of a pariah now,” Foster says. “But I am not anticaptivity. I am just pushing for the right thing.”

Foster had always prided himself on trying to understand the needs of the animals he was bringing into captivity so that he could help smooth the disorienting and stressful passage between the natural and human worlds. Getting accurate records on Tom and Misha proved impossible, but Born Free staff figured that the two had probably been captured near the large port of Izmir and then held in captivity for about four years. Tom was smaller, friskier, and seemed the younger of the pair. He was eager to please and appeared to have adapted better to captive life, swimming up to just about anyone who came out to the pen as if to ask, What’s up? What do you have for me?

Misha, in contrast, was standoffish and suspicious of anything new. When Foster tried to teach him to allow blood to be drawn from his fluke—necessary for monitoring his health—he

their ribs could be seen. Preparing them to re-join the world of wild dolphins would not be just a matter of teaching them how to hunt live fish again, reducing their contact with humans, and opening a gate. Foster knew he needed a more counterintuitive approach that would start with the same tools (a trainer’s whistle and target pole) and methods (“operant conditioning,” which rewards correct behaviors and ignores incorrect ones) used by marine parks all over the world to train dolphins to perform in shows.

Beyond being conditioned to allow blood draws—a process that involved getting Tom and Misha comfortable first with having their flukes handled, then pinched with a thumbnail or snapped with a rubber band to prepare them for the needle’s sting—both dolphins needed to learn to accept other basic health care procedures, such as allowing their blowholes to be swabbed for bacterial cultures. And Foster didn’t see how he could restore Tom and Misha to the Olympic level of fitness they would need to survive in the ocean if he didn’t first put them through a regimen of fast swims, jumps, and tail walks that would build muscle and stamina.

To wake up their dolphin brains, Foster dropped into the pen things they might not have seen for years, like an octopus or a jellyfish or a crab.

shied away at the first sight of a syringe. He disliked the blood draw so much that the next time he stayed in the middle of the pen, waving his fluke in the air as if to say, You can look at it, but don’t touch. He was reluctant to engage with the human world and often spent time in the pen looking seaward. “How dolphins view captivity depends a lot on how you bring them into captivity,” Foster says. “If you don’t have proper care and conditioning, you can end up with animals who are more neurotic.”

The lingering effects of Tom and Misha’s hard life in marine parks were evident in their lethargy and in the fact that they were perhaps 20 percent underweight, with so little blubber

“The only way is to train them so you can un-train them,” he says.

High-energy workouts require calories, so the first job was to overcome Tom’s and Misha’s picky eating habits and reacquaint them with the fish they would likely encounter in the Aegean, such as mullet, anchovies, and sardines. The strategy was to offer them a local fish species. If they ate it, they were rewarded with mackerel, a fish they’d developed a taste for in captivity. To mimic the unpredictability of food in the wild, Foster varied the amount and frequency of their meals. “When you bring them into captivity, everything from feeding to shows is very structured,” he says. “They develop a built-in



JEAN HUNG

In a holding tank at the Seoul Zoo, Taesan (foreground) and Boksoon learn to eat live fish again. They're scheduled to be released off Jeju Island this summer. If all goes well, they'll rejoin Chunsam in their native group.

clock and can tell exactly when they are going to get fed. We have to turn that around, because we know that in the wild they will eat more one day than another.”

Foster also wanted to wake up their highly capable dolphin brains. He dropped into the pen things they might not have seen for years, like an octopus or a jellyfish or a crab. He cut holes along the length of a PVC tube, stuffed it full of dead fish, and then plunked it into the water. Tom and Misha had to figure out how to manipulate the tube so that the fish would pop out of the holes. “In captivity we train the animals not to think on their own, to shut down their brains and do what we ask them to do,” Foster explains. “What we are trying to do when we release them into the wild is get them off autopilot and thinking again.”

The feeder tube had two other benefits. It floated about five feet below the surface, so Tom and Misha were reminded that food is found underwater. It also helped disassociate humans from the provision of food. “We had to get them to understand that fish doesn’t only come from a silver bucket and a person,” says Amy Souster,

a young marine mammal trainer who was drafted into the project by Foster.

Getting Tom and Misha ready was a step-by-step process that continued through the spring of 2011, with up to 20 learning sessions a day. By the time the hot summer months approached, Foster was hopeful that Tom and Misha would be ready to swim free in early fall. But in the summer heat, with the bay’s temperature climbing to a dolphin-stressing 80 degrees or more, Tom and Misha lost their appetites and were hit by a virulent blood infection that was barely staved off by emergency tube feeding and a heavy dose of antibiotics. “That almost certainly would have killed them within a few days,” John Knight, Born Free’s consulting vet, recalls. “It was a very close call indeed.” Tom and Misha didn’t have a close bond and mostly tolerated each other. But Souster was moved to see Misha trying to care for Tom, pushing him to the surface to help him breathe when he sank to the bottom of the pen and taking him fish in an attempt to get him to eat.

To make matters worse, by the end of the summer the villagers in Karaca had made

clear—by slashing the tires of Born Free cars, scratching them with keys, and eventually making rape threats against female staffers—that they were fed up with the project taking over their bay. In October 2011 the sea pen, with Tom and Misha inside, was carefully towed to a new location across the bay and anchored next to a sailing academy, which had generously offered the use of its extensive facilities. Foster and his team redoubled their efforts, with special emphasis on the dolphins' physical conditioning. One popular workout involved fast swims back and forth across the pen, the dolphin equivalent of wind sprints. Another was trying to get them to swim ten laps around the perimeter of the pen at top speed.

The pen was now anchored about a hundred feet from the wooded shore, allowing Foster to turn to a favorite innovation from the Keiko project: an oversize slingshot that rotated on a stand and could be used to shoot fish with impressive accuracy into different parts of the pen. In addition to delivering food without direct human involvement, the slingshot encouraged Tom and Misha to get in the habit of moving more, as wild dolphins do. They soon got the idea, and just the *thwap* of the slingshot triggered their predatory reflexes. "They didn't think. They would just wait for the next thing to hit the water," Foster says. "That was when I knew it was time to introduce live fish."

It's one of the oddities of captivity that wild-caught dolphins no longer seem to understand that live fish are to be hunted and eaten. Tom and Misha would watch schools of fish swimming through their pen as if they were watching television. Foster had to train them to hunt and eat live fish again. He started by mixing live fish—initially slowed down by a bang on the head or a cut tail—into handfuls of dead fish that would be thrown into the pool. Tom and Misha had become so used to racing each other to gobble up anything that dropped into the water that without thinking they would eat the live fish along with the dead ones. Over time live fish—slowed less and less—made up an increasing portion of their feedings, until the dolphins were once

again accustomed to the taste and to the idea that they had to catch their meals.

Foster next used five-gallon water jugs, with spring-loaded lids that could be opened remotely, to release live fish into the pen from multiple locations and at different depths, again taking humans out of the equation and focusing Tom's and Misha's attention underwater. Both dolphins started spending more time foraging for fish in the depths of the pen, even blowing bubbles from their blowholes to flush out fish hiding in spaces they couldn't get to. Souster had been skeptical that captive dolphins could successfully be returned to the wild. "But I watched Tom and Misha change from lethargic, people-oriented animals, focused on food coming from buckets, to animals that would go crazy for live fish and acting the way wild dolphins should act," she says. "It was incredible."

Foster agreed. It was time to open the gate.

May 9, 2012, was a crisp and promising cobalt-sky day. A large crowd of Born Free staff and supporters gathered nearby. Early that morning Tom and Misha had had tracking tags attached to their dorsal fins so that Foster and Born Free could monitor how they were doing out in the wild Aegean. "If they can make it alive through a six-month period, then we know they have been successfully reintroduced," Foster explains. "If they are not doing well, and at three months an animal is slowing down and its range is smaller and smaller, you know it is losing nutrition."

When all was ready, a scuba diver unzipped a door in the sea-pen netting. The big moment had arrived, but Tom and Misha stayed put, milling about cautiously inside the pen. After about 20 minutes of increasingly awkward inaction, Amy Souster extended her right arm and swept it downward across her body, giving them one last training signal: the signal to go from A to B. True to form, Tom did as he was asked and swam out of the pen, pausing about 30 feet away. As usual, Misha followed Tom's lead, but then accelerated

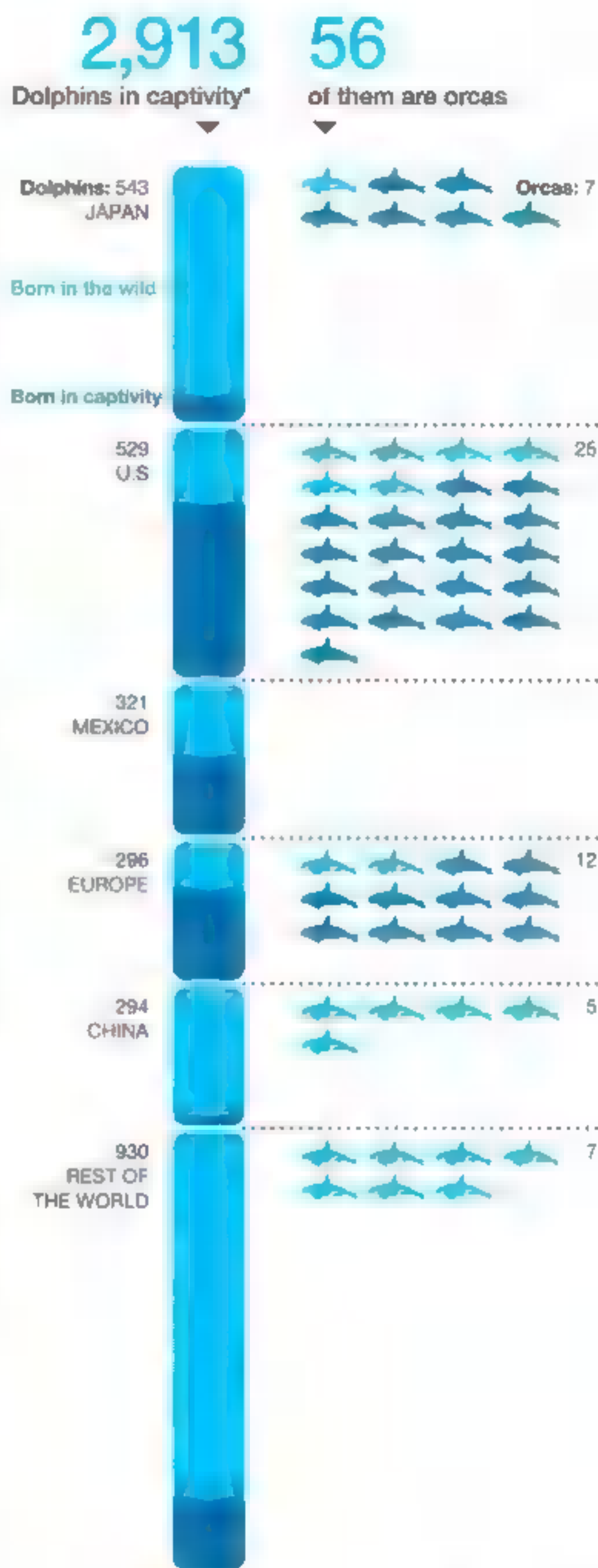
past him, sprinting toward the mouth of the bay. Tom raced to join him. If there'd been any doubt about how the two long-captive dolphins would react to the open ocean, it was soon erased. "Within six hours they were eating wild fish and swimming with another [dolphin]," Foster says. "It was fabulous."

According to their satellite tracks, the two dolphins swam mile after mile, heading toward Izmir, then after five days, they separated. Foster wasn't surprised. Tom continued swimming west. Misha headed south and east. "Once he was gone, he was gone," says Foster.

In mid-October, five months after the release, Tom's tracking tag stopped transmitting. Misha's kept pinging until late November and then went silent too. Foster and Born Free had hoped the transmitters would last nine months or more, but the tags had worked long enough to establish that Tom and Misha had adapted to their new lives back in the Aegean. It had taken 20 months and a million dollars, but Foster and Born Free had proved that even dolphins that had suffered greatly in captivity could be taught what they needed to know to live wild again.

A year later and half a world away, a similarly well documented release of three captive dolphins emphatically reinforced that lesson. On July 18, 2013, the net walls of a sea pen on the rocky northern coast of Jeju Island, a popular tourist destination off the southern tip of South Korea, were opened. Two Indo-Pacific bottlenose dolphins, Jedol and Chunsam, hung around for a short while and then swam out into the open ocean. Along with a female called Sampal, they'd been illegally captured between 2009 and 2010 from a group of about 120 wild dolphins that inhabit the waters around Jeju Island, then sold to Pacific Land, a sea resort on the island. A campaign by the Korean Animal Welfare Association resulted in a court order releasing them.

The three dolphins had been trained to perform all the usual tricks—jumps, tail walks, flips, and tail waves—in shows at Pacific Land.



Captive Performers

Dolphin exhibitions, primarily of bottlenose dolphins and orcas (killer whales), became popular in the 1960s. Today more than 300 parks worldwide feature marine mammals. Ninety percent of the cetaceans in captivity are dolphins; the rest include belugas and porpoises.

*JANUARY 2015 ESTIMATE; MANY COUNTRIES DON'T KEEP RECORDS. ALVARO VALUÑO AND TONY SCHICK. SOURCES: CETA-BASE; ORCA HOME





FLUKER *United States*

This SeaWorld orca killed a trainer in 2010. Captive for more than 30 years, he probably couldn't survive in the wild, say experts. Advocates argue that he should be moved to the more natural environment of a sea pen, ideally in his native Alaskan waters.

www.foxnews.com



KSHAMENK *Argentina*

Stranded in 1992, Kshamenk lives at Mundo Marino ■ Buenos Aires. Returning him to his family would be critical to his survival in the wild, but little is known about his native group.

Jedol was then traded to the Seoul Zoo, where he performed many of the same stunts in its dolphin program. Following the court order, Chunsam and Sampal were taken to the sea pen off Jeju Island in early April 2013; Jedol arrived a month later. The Seoul Zoo sent a trainer, Joo Dong Seon, to prepare the dolphins for release.

The three dolphins were well trained and in good condition, and they'd been captured when they were older and more experienced. So the strategy to get them back into the wild was simpler than the one used with Tom and Misha: reduce human contact as much as possible and make sure the dolphins were ready to survive on a diet of live, local fish. Within a matter of weeks the dolphins became proficient at chasing and

feeding on live fish, even learning to eat around any spines, just like their wild cousins. "At first I thought it was nonsense to release Jedol, because he was adjusted to the pool, he was used to dead fish, and four years is a very long time," says Seon. "I doubted he would relearn to hunt live fish. But once we were at the sea pen, I saw how fast the dolphins were learning."

As with Tom and Misha, food intake, fitness, weight, and health were carefully monitored to establish criteria for release. Sampal, however, had her own criteria and escaped through a small hole in the sea pen on June 22, following a big feeding. A few days later researchers using photo-ID techniques confirmed that she'd rejoined the wild dolphin pod. Three weeks later



INGRID VISSER

Jedol and Chunsam were released. Each had a number freeze branded on the dorsal fin and a satellite tag, which fell off after about three months. Soon both had joined Sampal in the wild group.

The Korean dolphin release demonstrated that with healthy dolphins, local support, and a dolphin group nearby, the transition from captive to wild could be relatively straightforward and take just a few months. It reinforced the idea that captive dolphins need not remain captive forever. "Probably one-third of dolphins in captivity check enough boxes to be candidates for release," says Naomi Rose, a marine biologist with the Animal Welfare Institute who advised the Korean Animal Welfare Association on the release.

Though Foster says he will no longer help capture dolphins from the wild for shows and thinks release is a workable option for many

captive dolphins, including some wild-caught killer whales, he still believes that captive display—if done right—can help humans and dolphins make a positive connection. He would like to see the aging captive-industry model of man-made pools and circus-style shows replaced by ocean pens with open gates as well as education and research programs. "You give the animals a choice, and to me that would be the happy medium," he says. "Tom would probably stick around. Misha would be gone."

These questions will be debated into the future, but Tom and Misha have played their part and disappeared into the wild. Anonymity is an important characteristic of being wild, and there's something heartening about their being given the freedom to vanish.

At the same time there's something beautiful about knowing the rest of a story. On a fine May day last year a small fishing boat came upon 60 to 70 Indo-Pacific dolphins working their way along the northeastern shore of Jeju Island. Some were hunting. Others were playing. With the frantic and slightly comical motion of the nervous young, small calves tried to keep up with their mothers. They were all wild dolphins living their wild dolphin life, a complex community with its own customs, rhythms, and priorities.

Suddenly a dolphin surfaced nearby with a small white "1" clearly emblazoned on its dorsal fin. It was Jedol. Not long after, a "2" appeared, announcing Chunsam's presence. The numbers looked bizarre and out of place in the wild serum. But they were deeply moving proof that the two dolphins were in exactly the right place: the wild ocean, where they'd been born and where they will now spend the rest of their lives. □

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BRIAN SKERRY



KEIKO (FREE WILLY) Norway

The famous orca swam free in 2002, after more than 20 years in captivity. He settled at a boat but continued to seek out human company and food handouts. Keiko was only a year old when his release prepared him back to other dolphins.

Storymags





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LIVING GODDESSES OF NEPAL

*In the Kathmandu Valley young
Newari girls called kumaris are
worshipped as omnipotent deities.*

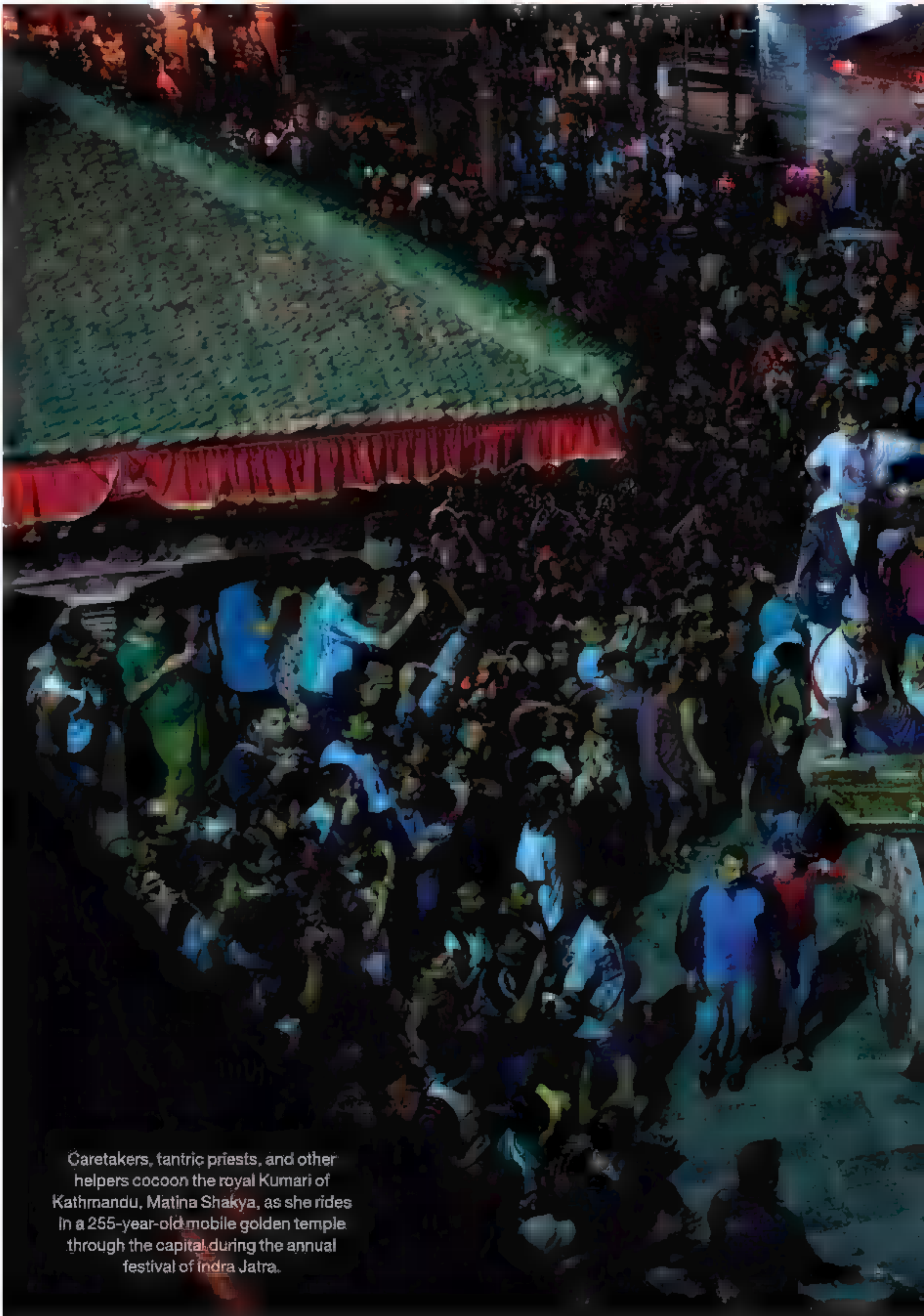


The Kumari of Jokha, nine-year-old Dangol, became a living goddess as an infant. A *kumari*'s eyes are believed to draw the beholder into direct contact with the divine. For religious festivals her forehead is painted red, a sign of creative energy.



Careful not to pollute herself by touching the ground on a day when the power of the goddess has been invoked, Dango is carried by her father to a palanquin that will bear her above the crowds during the festival. Bisket Jatra





Caretakers, tantric priests, and other helpers cocoon the royal Kumari of Kathmandu, Matina Shakya, as she rides in a 255-year-old mobile golden temple through the capital during the annual festival of Indra Jatra.



By Isabella Tree
Photographs by Stephanie Sinclair

Unika Vajracharya could be standing on the brink of divinity,

about to become one of Nepal's most celebrated figures. She is six years old, at present a simple schoolgirl. Despite her shyness, her eyes sparkle with curiosity. She isn't used to receiving strangers. A smile dimples her cheeks when I ask her what she'll do if, later today, she's chosen to be a *kumari*, or living goddess, a role that will bring people to their knees before her.

"I'll keep quiet," she says. "I won't be allowed to go to school. I'll study at home and receive worship every day."

Unika is a Nepali from the Newar ethnic group. She lives in Patan, officially known as Lalitpur, a city of 230,000 people of mainly Buddhist influence in the fertile Kathmandu Valley, in the foothills of the Himalaya. The Newars pride themselves on being the custodians of culture in the valley, and an age-long cornerstone of their culture is the worship of little girls as living goddesses.

The selection process involves a secret ritual from which even Unika's parents will be barred. Is she nervous? I ask. "No," she says, brightly. "Just excited."

As we leave her house—an old, low-ceilinged, brick-and-timber building in a neighborhood called Thabu—Unika skips along through the narrow streets, pulling her mother, Sabita, and elder sister, Biphasa, by the hand. It's a short walk to Hakha Bahal, the courtyard where for centuries members of her extended family have lived and gathered for religious rituals and festivals and where the first part of the selection will

take place. Unika's wearing her favorite yellow fleece hoodie with "Snoopy" on the back. If she's chosen, this will be one of the last times she'll be able to wear it. A living goddess can wear only red—the color of creative energy, usually reserved for married women. A woman, a neighbor, touches Unika's cheek as she passes. "Are you going for *kumari*, little one?" she asks.

Kumaris are revered in the Newar community. They're believed to have powers of prescience and the ability to cure the sick (particularly those suffering from blood disorders), fulfill specific wishes, and bestow blessings of protection and prosperity. Above all, they're said to provide an immediate connection between this world and the divine and to generate in their devotees *maitri bhavana*—a spirit of loving-kindness toward all.

The tradition dates back to at least the tenth century, when young girls and boys across South Asia performed in Hindu and Buddhist rituals as agents for divination. Their presumed connection to the divine and ability to predict the future were of particular interest to Asia's rulers. Centuries later the tradition was taken up by people who lived on the periphery of the Indian subcontinent—in Kashmir, Assam, Bengal, Tamil Nadu, and Nepal—and who followed subversive religions that emphasized female power, or *shakti*, and tantric possession, a state brought about by magical invocations and rituals in which humans supposedly can be transformed into divine beings with supernatural powers.

Unika Vajracharya, six, takes to her throne on her first day as the Kumari of Patan, her feet resting on an offering tray and ■ snake god guarding her head.



In the family living room Unika plays with her younger brother, as her parents debate whether to offer her for selection as a kumari. The incumbent girl has been dismissed because she got her first period.

Only in the remote mountain fastness of Nepal did the practice of glorifying prepubescent girls (in Nepali the word “kumari” means “virgin girl”) as living goddesses for years at a time become a deeply rooted cult, and only in Nepal is the tradition nurtured with vigor today. To Newar Buddhists, the kumari is regarded as the embodiment of the supreme female deity Vajradevi, a Buddha. To Hindus, she incarnates the great goddess Taleju, a version of Durga.

Today there are just ten kumaris in Nepal, nine of them in the Kathmandu Valley. They’re still selected only from families attached to certain *bahals*, or traditional courtyard communities, and all their ancestors must have come from a high caste. Being chosen for the position is regarded as the highest honor, one that can bestow innumerable blessings on a kumari’s family. So despite the financial burden and personal sacrifices involved in maintaining a young girl as a living goddess in the modern world, and the challenges of her rehabilitation once she reaches puberty and has to live a normal life again, certain families are still prepared to put their daughters forward for selection.

THIS IS UNIKA’S second time as a candidate for kumari. She was two years old the first time, too young to remember the esoteric rituals of the selection process. It’s partly Unika’s own eagerness that has persuaded the family to put her forward again. She longs to dress up like a kumari, her hair bound into a topknot on her head, thick kohl lines drawn around her eyes right up to the temples, and on festival days, a

*Isabella Tree first saw a kumari when she visited Kathmandu as a teenager in the 1980s. Her book *The Living Goddess* is the result of 13 years’ research. Stephanie Sinclair’s work centers on women and girls around the world.*



red tika painted on her forehead with a silver *agni chakchuu*—the third eye, known as the fire eye—staring out from the center. This desire to wear the kumari ornaments is in itself considered something special, a sign perhaps that fate, or karma, is pulling her.

Unika’s grandmother Masinu worries that the little girl will be disappointed if she’s not chosen this time. “My hopes are with her. I don’t want her to feel sad.”

Unika’s father, Ramesh, who runs a small shoe shop, has other concerns. “I’m worried about the costs,” he tells me. “And the purity restrictions



Being chosen for the position of kumari is regarded as the highest honor.

that would be imposed on the family.”

A kumari is an onerous responsibility for all, one that would weigh heaviest on Ramesh as the family’s breadwinner. She must wear special clothes and makeup every day and have new festival dresses made of expensive cloth at least twice a year. A room in the house—a precious commodity in the overcrowded city—must be set aside as a *puja*, or worship, room with a throne where the goddess can receive devotees. The family must perform *nitya puja*—daily worship rituals—before her every morning. She cannot go outside, except on festival occasions,

and then she has to be carried, either in someone’s arms or in a palanquin, so that her feet don’t touch the ground. She can eat only certain foods and no taboo items, such as hen’s eggs or chicken. Everything in the house has to be kept ritually pure. No one in contact with her can wear leather. Above all, the kumari must not bleed. It’s believed that the spirit of the goddess, the shakti, that enters the girl’s body when she becomes a kumari, will leave her if she loses any blood. Even an accidental graze could end her reign. A living goddess is always dismissed when she gets her first period.

Ramesh also is worried about his daughter's future should she be chosen. She's expected to return to normal life, but after years of pampering and seclusion, the transition from goddess back to mortal can be difficult. Then there are the dark rumors about the marriage prospects of former living goddesses. "Men are superstitious about marrying ex-kumaris," Ramesh says. "They believe terrible accidents will happen to them if they try." The spirit of the goddess may still be strong in a former kumari, it is said, even after the diffusing rituals she undergoes upon her dismissal. Some believe that snakes issue from the vaginas of former kumaris and devour the hapless men having intercourse with them.

In Patan only girls from the Buddhist lineage of Hakha Bahal are eligible to become kumaris, and in the end it was the persuasive powers of the bahal elders, and the desire to continue tradition, that won the day.

"We need to uphold the ways of our ancestors," Sabita tells me. "It is our duty to provide a living goddess from our community." In the Kathmandu Valley people have a strong reverence for the past, a sense that in times gone by there was a deeper connection with the gods and that for this reason ancient customs must be followed—even if, in the 21st century, they're no longer fully understood.

kumari, representing one of the living-goddess traditions in the valley. In recent years the tradition has come under criticism from human rights activists who say it's a form of child abuse that hinders the girls' freedom and education and is especially detrimental to the royal Kathmandu and Patan kumaris, who must observe strict rules of purity and segregation.

But in 2008 Nepal's supreme court essentially rejected a Newari woman's petition against the tradition, citing its cultural and religious significance. Four kumaris—in Kathmandu, Patan, Bhaktapur, and Nuwakot, a fortress on the trade route into the valley from Tibet—receive government support in the form of a monthly stipend while in office and a pension for life when they retire. In real terms, though, the value of this grant barely covers the cost of clothes and worshipping materials.

The courtyard of Hakha Bahal, with its towering pagoda roofs, wooden resting platforms, and repoussé bronze shrine to the Buddha Akshobhya—now encased in an ugly antitheft metal cage—is crowded by the time Unika, Sabita, Biphasa, and I step inside. Amid the throng of local spectators and well-wishers is three-year-old Anjila Vajracharya. She's the only other kumari candidate, and she's dressed for the occasion, perhaps optimistically, in red, like a kumari.

Ananta Jwalananda Rajopadhyaya, the head

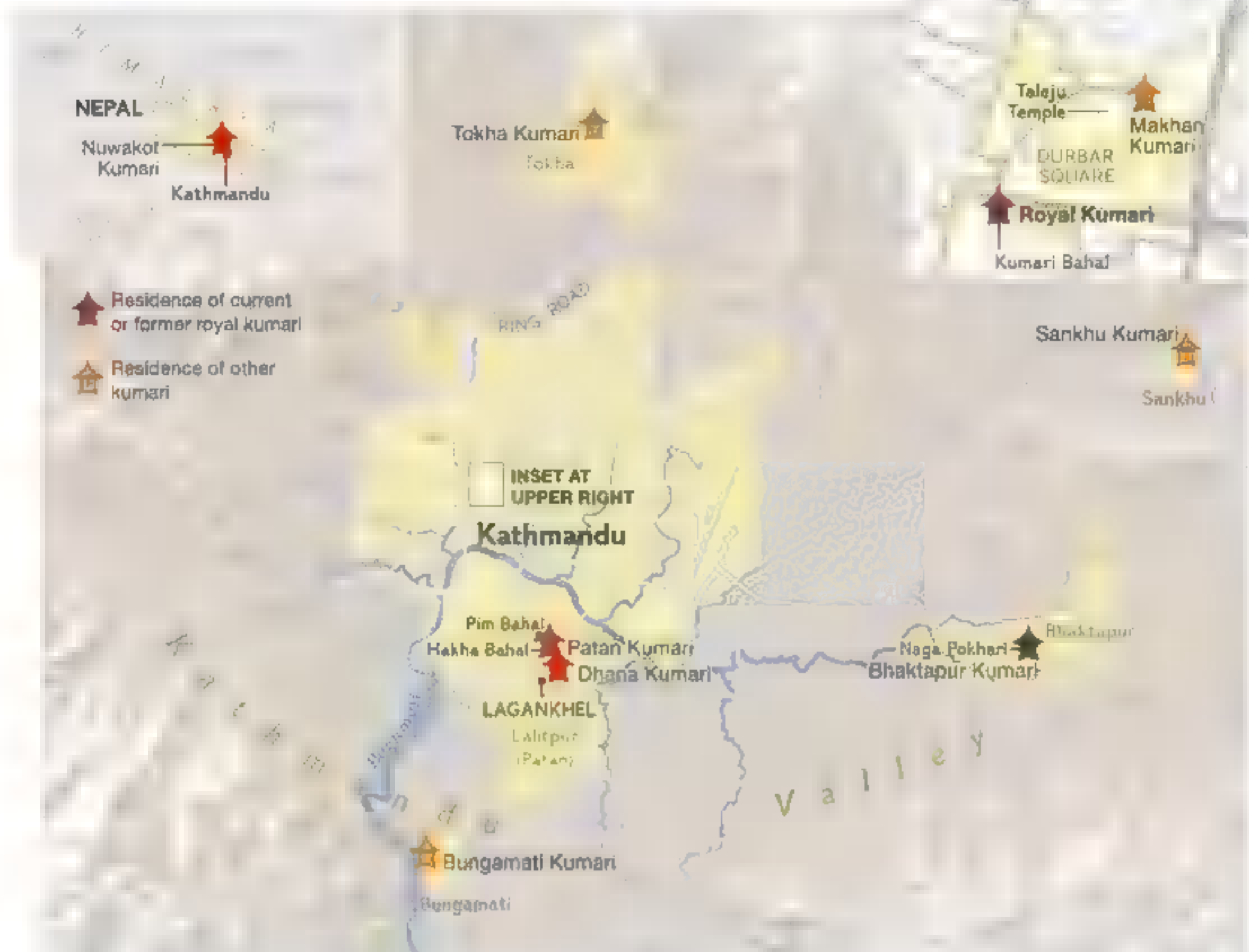
The family must perform daily worship rituals before her every morning.

IN MEDIEVAL TIMES almost every town in the Kathmandu Valley had its own kumari. In the cities of Kathmandu, Bhaktapur, and Patan there was one for almost every locality, as well as a special "royal" kumari, worshipped by the former Hindu kings. Many traditions have since disappeared, some only in the past few decades. In Mu Bahal, a courtyard community five minutes' walk north of Kathmandu's Durbar Square, devotees have been worshipping an empty throne since their last kumari retired, in 1972. The Patan Kumari is a royal

priest of the Taleju Temple—which adjoins the old royal palace where Patan's kings used to worship the royal kumari as their lineage goddess, Taleju—is waiting in the courtyard. This is the first time, the 77-year-old priest tells me ruefully, that there have been only two candidates for the final selection. It would be auspicious to have three. He blames family planning for the dwindling pool of eligible girls to select from and says parents are also becoming more reluctant. "People are not used to following the religious disciplines these days.

Nepal Kumaris

Ten kumaris are worshipped today near Kathmandu. The tradition remains strongest in the ancient royal cities such as Patan, or Lalitpur.



They are becoming distracted by other things.”

Rajopadhyaya regrets that few people today know how to identify the 32 *lakshina*, or signs of perfection. Traditionally priests examined the candidates to identify these signs—thighs like a deer, chest like a lion, neck like a conch shell, body like a banyan tree, a gold complexion, the soft voice of a duck, and so on—which are indicative of a bodhisattva, or enlightened being. “Nowadays,” he says, “we simply ask the parents to make sure their daughters are healthy and have no blemishes or birthmarks. Then we check their horoscopes.”

Every Newar has a horoscope, drawn up at birth by an astrologer. A hand-painted scroll of complex tables and diagrams kept in a strongbox in the family worship room, the horoscope bears a person’s private birth name and the astrological signs believed to influence his or her life. A

candidate’s horoscope must have no inauspicious indications. The most favorable sign for a kumari is the peacock—symbol of the goddess.

Rajopadhyaya takes the two girls behind a closed door in a corner of the courtyard for the secret first step in the selection. This is intended to whittle down the number of candidates to three. But since there are only two girls, it’s just a formality, over in minutes.

The final selection is made by his wife, Maiya, at their house, a concrete building under construction in the neighborhood of Pim Bahal, to the north of Hakha Bahal. It takes us—a procession of 40 or so onlookers and well-wishers following the priest, kumari candidates, and their families—ten minutes to get there, dodging the traffic along Patan’s main thoroughfare.

Having prepared herself through meditation, Maiya is waiting in an empty room upstairs, lamp,



Like other kumaris, Dangol wears special makeup for festivals. But it's more than makeup that changes on these occasions. Former kumaris have described feeling bigger and stronger and said that heat radiates from their foreheads.





The most favorable sign for a kumari is the peacock—symbol of the goddess.

waterpot, garlands of flowers, puja trays, bowls of curd, leaf plates of beaten rice, known as *baji*, and other ritual paraphernalia laid out on a part of the concrete floor that's been smeared with a purifying mixture of red clay and cow dung. The girls, separated from their mothers, are seated on red cushions facing her. Little Anjila is excited and leaps from her cushion to Unika's and back again. Unika sits rock still, but her eyes dart about the room. All the onlookers, including the two candidates' mothers, are directed to leave. Only Maiya and an assistant, a daughter-in-law, remain inside with the candidates.

Crammed in the dim stairwell outside, with daylight fading, we're alert to the hum of mantras, the tinkling of a handbell, and the aroma of incense wafting from the room. Moments later we hear Anjila begin to wail. By the time the door is opened again, she's hysterical and rushes to her mother. Unika remains perfectly composed on her cushion. There's an air of release after the agonizing suspense.

With growing aplomb, the kumari-elect begins to receive offerings from her well-wishers as, one by one, they kneel and bow their foreheads to her feet. From now on, she'll no longer



be known as Unika but Dya Maiju—Little Girl Goddess. It's not only her steady demeanor that confirms for the supplicants the presence of the goddess within her. Much to the priest's gratification, her horoscope, scrutinized moments before the ritual began, bears the portentous sign of the peacock.

SAMITA VAJRACHARYA, the outgoing kumari, had been conspicuous by her absence at the gathering in Hakha Bahal. Though her house overlooks the courtyard, she had been too shocked by her dismissal five weeks earlier,

Even a goddess, two-year-old Resuka, the Kumari of Kilagal, refuses her food. It's believed that if Resuka and the royal Kumari of Kathmandu, who lives nearby, ever see each other, their souls will leave their bodies.

following the start of her first period, to make an appearance.

Months later I met with 12-year-old Samita in her friend Chanira Vajracharya's house on the busy main road, just yards from Hakha Bahal. Chanira had been the Patan Kumari before Samita. Their families had always been close, and their shared experience as living goddesses had brought Chanira and Samita closer still.

We sat together on flat cushions on the floor, photographs of previous kumaris staring down at us from the walls. In black leggings and an orange top featuring a furry koala, Samita, a talented player of the sarod, a type of lute, had just come from a music lesson. She was accompanied—as always—by her mother, because crowds, traffic, public transport, noise, uneven pavements were all too daunting for her on her own. Strangers also were unnerving. Although she smiled as I asked questions, her lips remained firmly sealed.

"As a kumari, you never speak to outsiders," Chanira explained, while Samita stared resolutely into her lap. "It was a year or so before I could manage a conversation with someone I didn't know. Even now, at college, I find it hard to stand up in front of the class to present my work."

Chanira, 19, is studying for a bachelor's degree in business administration at Kathmandu University School of Management. Tutored at home by teachers who gave their time for free while she was the kumari, Chanira had been given her "school leaving certificate," graduating with distinction. Bright, expressive, impressively fluent in English, it was hard to imagine she'd ever been at a loss for words.

"I was 15 when I got my period, so I was waiting for it to happen," Chanira said, "but Samita was only 12, so it was more of a shock. It's a really emotional time. When you give the goddess's ornaments and throne to someone else, it feels



Unika sits on her throne in a shop in Lagankhel, as an attendant adjusts a silver necklace believed to imbue her with godly power. The newly selected Kumari Patan's first official role is to witness the ritual bathing of the image of a rain god.



Off duty, Unika displays the exuberance of any child, but she's never reprimanded. In games with her little brother and older sister, she's always the boss. No one risks the wrath of a living goddess.

like someone has died. You're in mourning."

What was it like for Samita when she was dismissed? I asked. Chanira repeated the question softly in Newari for her friend, painstakingly translating her whispered responses.

For Samita, the weeks directly after the appointment of her successor had been exceptionally painful. Ideally a kumari should live next to her ancestral courtyard. Unika's family had stayed with Samita's for a month while accommodations were made ready for them next door. Every day Samita had watched devotees queuing in the family sitting room, while another little girl took up the throne in her old puja room.

Now Unika and her family—and the kumari throne—had moved to the house next door. Samita was at school and making headway. She had friends, some of whom had visited her throughout her three and a half years as the kumari. But she still dreamed sometimes that she was the kumari—dreams from which she would wake up with a pang of regret.

What does she want to be when she finishes school? I asked. Chanira translated Samita's muted response. "She wants to be a musician." And what about marriage—presumably that is out of the question? I asked, remembering what Ramesh had said about terrible accidents happening to the husbands of former kumaris.

"It's not true, these rumors about husbands of ex-kumaris dying," Chanira said. "It's a myth that is always repeated in the media." In fact nearly every former kumari of marriageable age, whether in Patan, Kathmandu, or anywhere else in the valley, is married.

Would you both be happy for a daughter of yours to become a living goddess? "We can't marry within our lineage," Chanira said, "so it's unlikely either of us would have a daughter who would be eligible. I suppose if we married

someone from our caste from Kathmandu, she could become Kathmandu Kumari." The two of them conferred, giggling at the thought of a husband. "Then, yes, we would both be happy if the goddess chose our daughters.

"Being kumari is a gift. I feel blessed that I was chosen," Chanira added. "But there are things that should be improved for the welfare of the kumaris. Like greater financial support from the government to cover the expenses of rituals and the goddess's education. And counseling to explain how her life will change after she finishes as kumari. I'd like to see a support network of





“Being kumari is a gift. I feel blessed that I was chosen.” —Chanira Vajracharya

former kumaris helping those who’ve just been dismissed. I’m worried that if we don’t see these changes, we may lose the tradition altogether.”

Chanira later took me to encounter Patan’s new living goddess. The kumari’s eyes flashed as I entered the puja room. She was sitting on the golden throne, silver staffs of office on either side, a canopy of golden cobras spreading their hoods above her head, protecting her as they’d once protected Samita, Chanira, and generations of previous kumaris.

The face in front of me was familiar as Unika’s, but it was hard to believe this was the

little girl I’d met on her way to the selection five months before. Her gaze bored into me with an aura of imperiousness that made me feel like a child myself. Around her neck hung a silver amulet. Her feet, adorned with silver bell anklets and stained with vermilion, rested amid rice and flower petals on a bronze offering tray. Kneeling on the rice mat before her, I offered a coloring book, crayons, and a modest donation of Nepali rupees. Deftly, she dipped her fingers into a dish of vermilion paste at her side, and I craned forward to present my forehead for her blessing. □




Lake O'Hara, located in the Canadian Rockies at more than 6,000 feet, "is an emerald in a bowl of mountains," wrote paleontologist Charles Walcott in 1911. Generations of artists have put brush to canvas at this lookout, called St. Soris Prospect.



Canada's Little Park of Wonders

*Once a whistle-stop on a wilderness
railroad, Yoho National Park is now
a hot spot of science and scenery.*





More than two dozen Yoho peaks clear
10,000 feet, including the snowy crags
of the Ottertail Range. Thrust up by
the collision of tectonic plates, these slabs of
stone once layed on primordial seafloor.

By McKenzie Funk

Photographs by Peter Essick



century ago on the flanks of Mount Field in Canada's Yoho National Park, Charles Doolittle Walcott, then secretary of the Smithsonian and one of the most famous paleontologists of his day, found two life-changing things. The first discovery was what is arguably the world's premier fossil

bed, a quarry that now bears his name. The second discovery was his third wife, Mary Vaux, after whose family he would soon name a genus of fossilized sponges, *Vauxia*.

It is natural that modern visitors to this most sublime and overlooked of the Canadian Rockies parks would focus on the first of these discoveries. The Burgess Shale formation that encompasses the Walcott Quarry was named a UNESCO World Heritage site in 1980. A few years later, in the best-selling book *Wonderful Life*, the evolutionary biologist Stephen Jay Gould called the Burgess Shale "the most precious and important of all fossil localities." It's a trove of perfectly preserved Cambrian sea creatures—more than 200,000 weird-looking specimens found, with countless others still to be discovered.

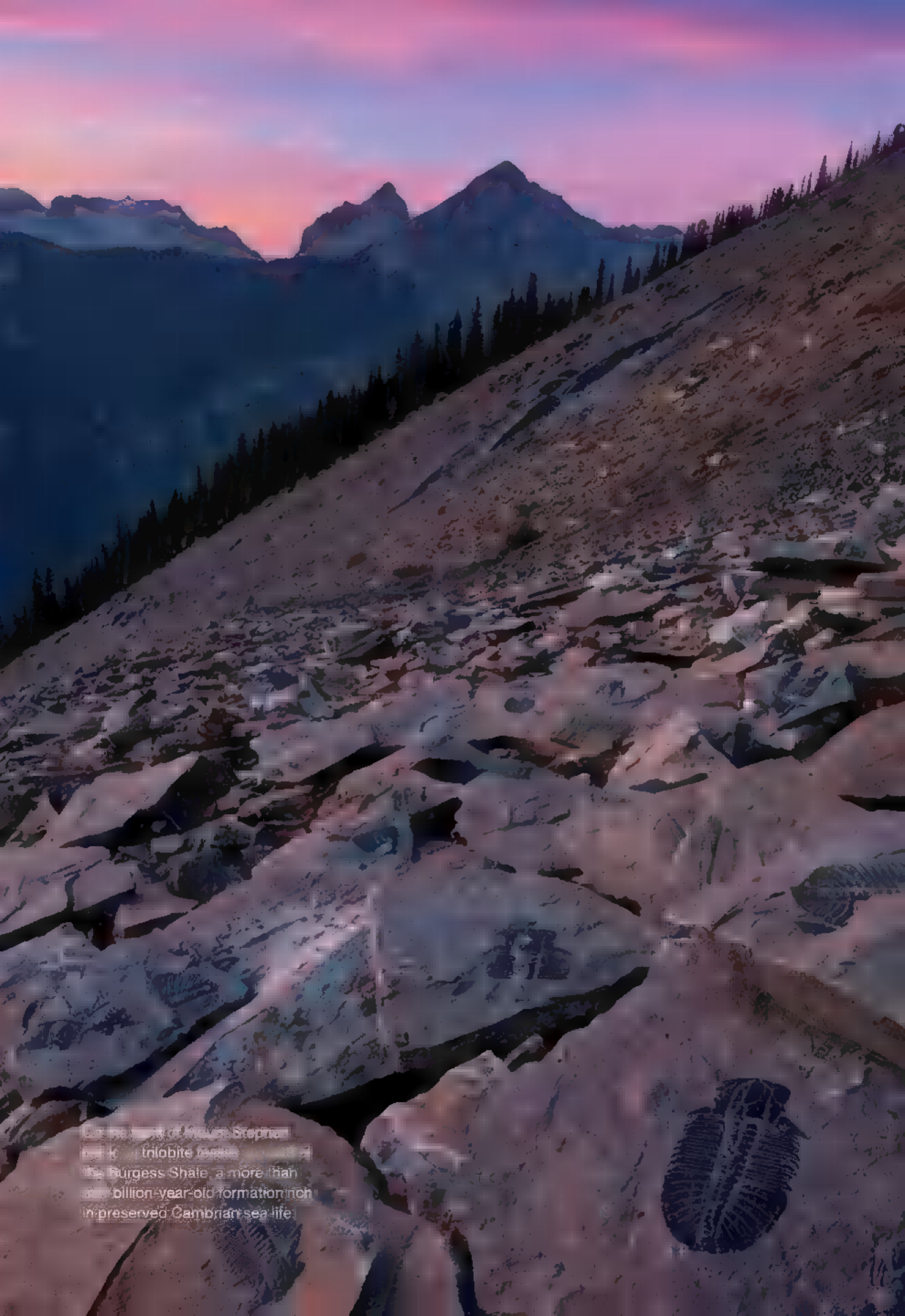
Yet most Burgess Shale life-forms—from spike- and armor-covered *Wiwaxia* to *Opabinia*, a soft-bodied bottom-feeder with five eyes and a claw at the end of an elephant-like trunk—appeared to Gould and others to be evolutionary dead ends, with no modern descendants. Gould used the explosion of Cambrian life and

subsequent disappearance of most evolutionary lineages to argue that "survival of the fittest" has an important counterpart: luck of the draw. Is evolution partly a lottery? Is natural history governed by chance? A scientific debate has raged ever since—but most of it far outside the borders of the national park. To understand the allure of Yoho itself, it's better to focus on the remarkable woman who was also on that mountainside, Mary Vaux, whose family has its own story of how serendipity can look like destiny.

On a sunny but cold August day, I woke up in Field, British Columbia, the 150-person town that houses Yoho park headquarters plus one hotel, one café, one restaurant, one post office, and one elementary school, and I set out by car for the nearby Yoho Valley. Around 1900, Mary, the eldest child in a prominent Quaker family from Philadelphia, was the first white woman to visit the valley. "It is to me the loveliest spot to be found, and it always quickens my blood when I hear and speak of it," she later wrote in a letter to Walcott. "I can imagine no greater delight than camping there away from the tourist, and the noise of the iron horse."

On my way there, I passed the Honda SUV of her grandnephew, Henry Vaux, Jr., which was parked outside a guesthouse, then crossed the

McKenzie Funk is author of Windfall: The Booming Business of Global Warming. Photographer Peter Essick is a regular contributor.



Close-up view of fossiliferous Steptoean
trilobite fossils preserved in
the Burgess Shale, a more than
500-million-year-old formation rich
in preserved Cambrian sea life.



Storage.com





train tracks that brought the first curious Vauxes here 128 years ago, then turned right on Highway 1, the Trans-Canada Highway, which runs through the middle of the national park. Yoho is small, an area of about 500 square miles—a fifth the size of adjacent Banff National Park, east over 5,344-foot Kicking Horse Pass and the Continental Divide, and an eighth the size of Jasper, just to the north. But its name, a Cree expression of awe, signals that its wonders are densely packed: at least 25 named peaks above 10,000 feet, two historic mountain lodges on two glacial lakes whose water is an otherworldly shade of turquoise, and hundreds of waterfalls, including Takakkaw, one of the tallest falls in

Canada, which I saw at the end of my drive up the Yoho Valley. The crowds here are mild compared with Banff's 3.5 million annual visitors, so much so that hikers can't hold themselves back. Sometimes when they pass each other, I noticed, instead of "Hello," they exclaim, "Yoho!"

The reaction of the Vauxes when they first visited British Columbia in 1887, shortly after the train line opened, was a more refined version of the same. The mountains were "cold, severe, beautiful, grand, unapproachably majestic," wrote Mary's middle brother, George Jr. The youngest sibling, William, focused on the "air full of the delicious odor of the forest ... and the wonderful harmony of light and shade." Below

Rogers Pass, close to Yoho in what is now Glacier National Park, they trekked to the toe of the great Illecillewaet Glacier—Mary, then 27, while wearing a black Victorian dress and a sun hat. The crevasses and towering seracs were like nothing they had ever seen. The Vauxes did what any modern tourists would do in the face of such beauty: They photographed it. The difference was that at the turn of the 20th century a camera was a large wooden box and most “film” was a plate of glass that had to be carefully transported in and out of the mountains and back to civilization—and they were capturing some of the first images of a hitherto undocumented wilderness. “So little exploration has been carried out that each visitor is practically a new discoverer,” wrote George Jr. It was the beginning of their transformation into amateur scientists.

When the family returned in 1894, during one of almost 40 summers Mary would spend in the Canadian “Alps,” they were surprised to find that the Illecillewaet had shrunk. Their photographs held the proof. Their camera, they realized, could be a scientific instrument. William, an engineer, was particularly intrigued by the retreat of the glaciers, and the Vauxes began documenting the shifting landscape with what they called “test photographs”: the same shot taken from the same place, year after year, for the greater part of two decades. They also carefully mapped glaciers and moraines with surveying equipment.

Back in Philadelphia they presented lantern slide shows to a curious public and, led by William, wrote well-received scientific papers. In Canada theirs was the first continuous glacier study of its kind, and it’s still referenced by scientists. At least eight decades ahead of modern concerns about global warming, “a big subset of the glaciers on the North American continent were receding,” says grandnephew Henry Jr., a University of California professor emeritus in resource economics. “This would be a significant discovery even now, and it was done by amateurs.”

Even after William’s early death in 1908 from tuberculosis and George Jr.’s gradual return to

Yoho is small, an area of about 500 square miles—a fifth the size of adjacent Banff. But its name, a Cree expression of awe, signals that its wonders are densely packed.

his Philadelphia law practice, Mary kept coming to Yoho. She walked many miles on Rocky Mountain trails before her death in 1940. She became the first woman to climb 10,502-foot Mount Stephen, and thus the first woman to climb a major Canadian peak. She camped in canvas tents near majestic Lake O’Hara while porcupines “tried the flavor of our bacon and the softness of the guides’ bed,” she wrote. She published stories about her adventures, doing “more to advertise the Canadian Rockies by magazine articles and photographs than perhaps any other living writer,” according to the Banff newspaper at the time. She took up botanical painting and published a five-volume set of illustrations that brought her praise as the “Audubon of botany.”

Quakers in the Victorian era were not meant to pursue such frivolities as art for the sake of art, but in the Vauxes’ black-and-white photos of the mountainous landscape—waterfalls, bogs, glaciers, forests, clouds—there is also an undeniable eye to aesthetics. “They were liberal Quakers,” says Henry Jr., so perhaps “they did art in the guise of science.” It is this aspect of their photos that drew him to take up his ancestors’ Yoho obsession a century later. Since 1997 he has come here for a month almost every summer, attempting to re-create 50 of the Vauxes’ most beautiful images with his medium-format camera—“test photographs” of his own. It has taken him more than a decade to capture shots of the quality he feels is demanded of a Vaux. So it is that one can now say with amateur-scientific authority what about Yoho has



Quartz pebbles in weathered sand give this rock a mottled appearance. These are called concretions—geologic nodules formed when salt and other minerals cement soft, sedimentary rock together in a hard, boulder case.



changed in the past century: remarkably little. There are now airplanes overhead. The forest near Kicking Horse Pass, often on fire during the construction of the railroad, has regrown. The glaciers have receded all the more. “But what has surprised me most is how little everything else has changed,” Henry Jr. says. He mentions the photo he recently took of Laughing Falls, a few miles from Takakkaw. “I could lay it out on the floor next to the one they took—and you wouldn’t be able to tell which is which.”

In the Yoho Valley that August morning, I met a guide—now required for the backcountry hike to the protected Walcott Quarry—near the base of Takakkaw Falls. We wound our way up steep switchbacks through a forest of spruce and fir and burst into the alpine zone just beyond Yoho Pass, a thousand feet up. As we traversed the steep scree slopes of Wapta Mountain, a vast basin opened up before us, framed by hanging glaciers and the soaring peaks of the President Range. Stunning Emerald Lake—its name is truly its color—was below. The quarry and Walcott’s camp, where he and Mary stayed for months at a time, were straight ahead.

“From the vicinity of the Burgess Pass camp the views were most beautiful and varied,” wrote Walcott in this magazine in June 1911, “and changed from hour to hour during the day and from day to day with the varying atmospheric conditions.” Even he, the great paleontologist, was not immune to Yoho’s aesthetics. Here he made one of the first panoramic photos to appear in *National Geographic*. “Mr. Walcott’s panorama is the most marvelous mountain view that has ever been published,” wrote the editors. Privately, Walcott admitted that Mary was the better photographer.

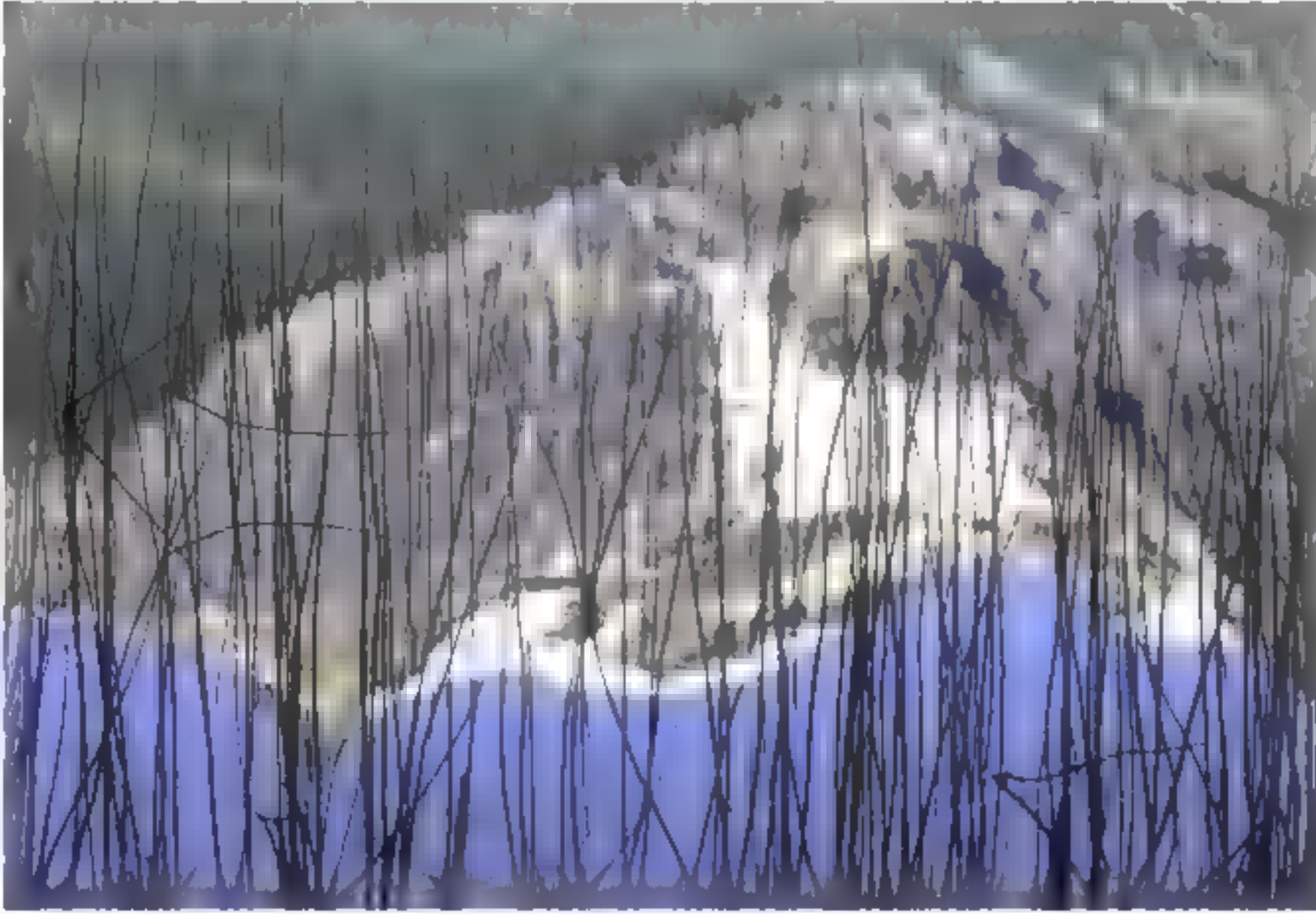
We were still at the fossil bed when the sun set. I would like to tell you that we passed our hours there combing through the trilobites, pondering evolution and the role of serendipity. But mostly we sat in silence and watched as an orange light suffused the basin. Then out of our pockets came cell phones and digital cameras, and in the name of science we did what visitors to these mountains naturally do. □





Stark mountains surrounding Lake
McArthur reveal Earth's history in layers
of stone — one reason Charles Walcott
considered Yoho "a geologist's paradise."

Stereomags.com



Fenced by reeds, Emerald Lake reflects blue sky and snowy Michael Peak flanked by woodlands (left). Late afternoon rays slice the Wapta Icefield (bottom left), a run of glaciers along the Continental Divide. Takakkaw Falls (right), one of Canada's tallest waterfalls, is half frozen, half flowing on a March afternoon.





For millennia the Aral Sea reigned as one of the planet's largest inland bodies of water, straddling what is now Kazakhstan and Uzbekistan. Today its decline serves as a cautionary tale.

Sins of the Aral Sea

In Kazakhstan a stretch of the former seabed has become a salt pan laced with cotton-farming chemicals.



By Mark Synnott

Photographs by Carolyn Drake

“**T**his is what the end of the world looks like,” says Yusup Kamalov, sweeping his hand toward the scrub-covered desert stretching before us. “If we ever have Armageddon, the people of Karakalpakstan are the only ones who will survive, because we are already living it.”

From our perch atop this sandy bluff in northern Uzbekistan, the view could be of just about any desert—that is, if it weren’t for the mounds of seashells and the half dozen marooned fishing boats rusting into the sand. This spot was once the tip of a peninsula jutting into the Aral Sea, which up until the 1960s was the world’s fourth largest inland body of water, covering some 26,000 square miles—an area larger than the state of West Virginia. Behind us lies the town of Muynoq, formerly a thriving fishing village with a sprawling cannery that even as recently as the 1980s processed thousands of tons of fish annually. Fifty years ago the southern shore of the Aral was right where we stand; now it lies 55 miles away to the northwest.

Kamalov has brought me here to see what’s left of the once bountiful sea. He’s a 64-year-old senior researcher in wind energy at the Uzbekistan Academy of Sciences. He’s also an environmental activist, chairing the Union for the Defense of the Aral Sea and Amu Darya. Heavyset, with a flowing mane of white hair, Kamalov descends from an influential Uzbek

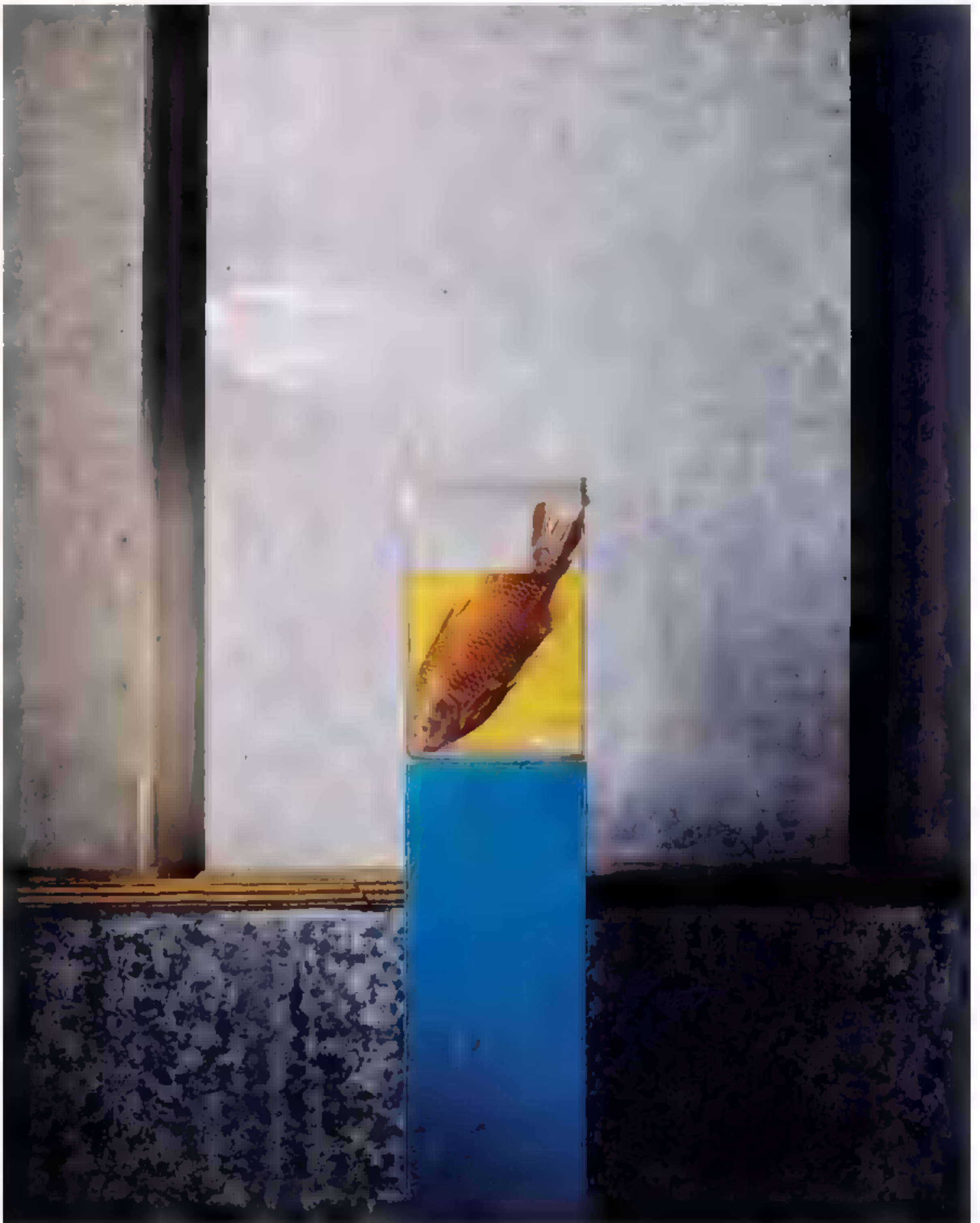
family: His father was a renowned historian during the Soviet era, and his grandfather was the last elected khan, or leader, of the semi-autonomous republic of Karakalpakstan before it became part of the Uzbek Soviet Socialist Republic during the 1930s.

His country doesn’t yet have a single wind farm, but that hasn’t dampened Kamalov’s enthusiasm for his chosen professional field. His obsession with wind has led him to build two hang gliders, which he flies from a local hilltop to better understand the air currents.

“I want to know the wind like a bird does,” he says. But his interests extend to all parts of the environment, and he has taken time off from his research to show me the remnants of what was once a massive body of water teeming with life and, perhaps more ominously, what the retreating waters left behind.

THE ARAL SEA STRADDLES Kazakhstan and Uzbekistan and for thousands of years was fed by two major rivers, the Amu Darya and the Syr Darya. Having no outflow, the sea’s water level was maintained through a natural balance between inflow and evaporation.

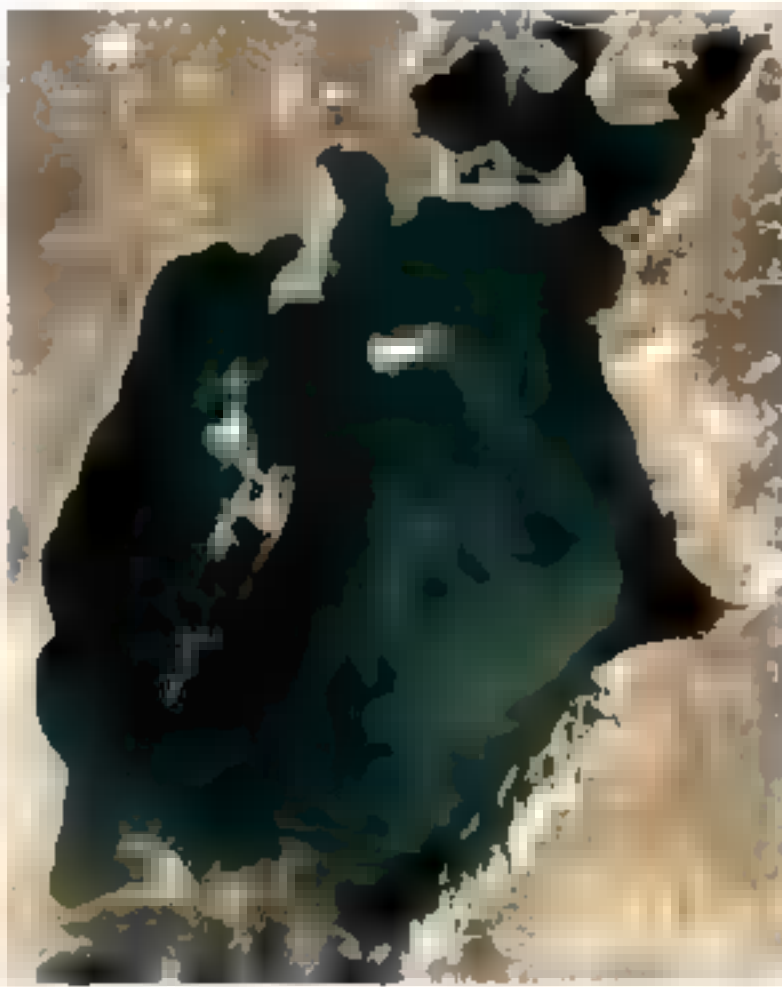
When Alexander the Great conquered this territory in the fourth century B.C., these rivers already had a long history of providing lifeblood to Central Asia. For centuries the Aral Sea and its vast deltas sustained an archipelago of settlements along the Silk Road that connected



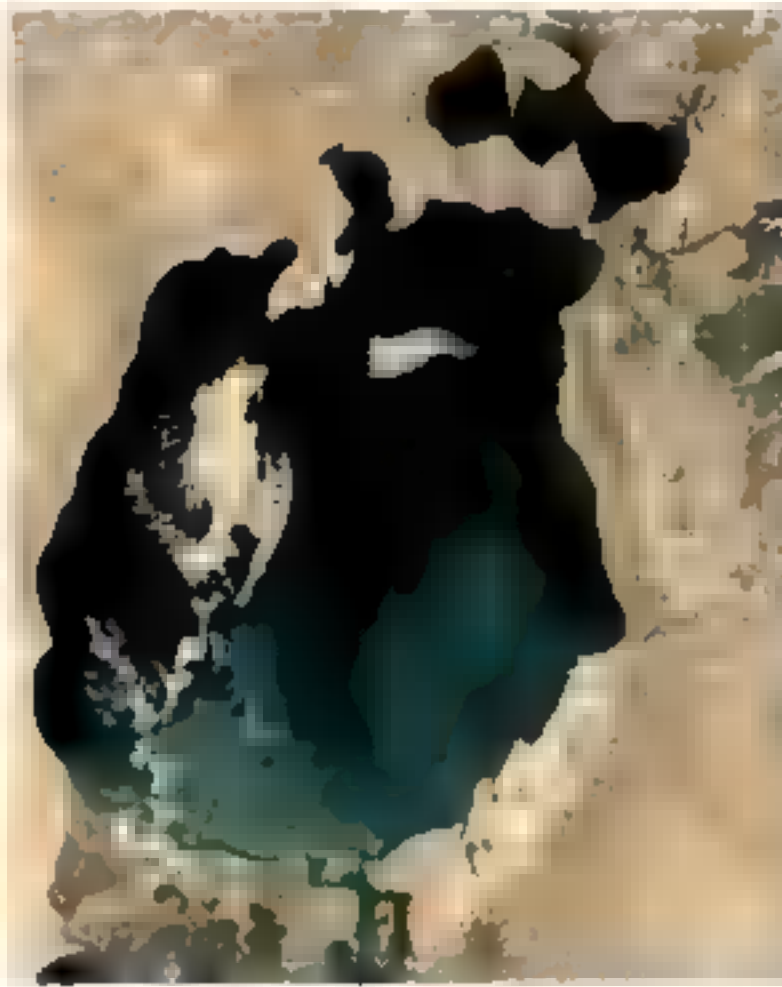
The History Museum in Aral, Kazakhstan, displays a preserved bream — one of several species that vanished in the 1980s, when the once bountiful Aral Sea shriveled and divided into separate bodies. On the Kazakh side, a dam has revived fish. On the Uzbek side, only invertebrates remain.







1977



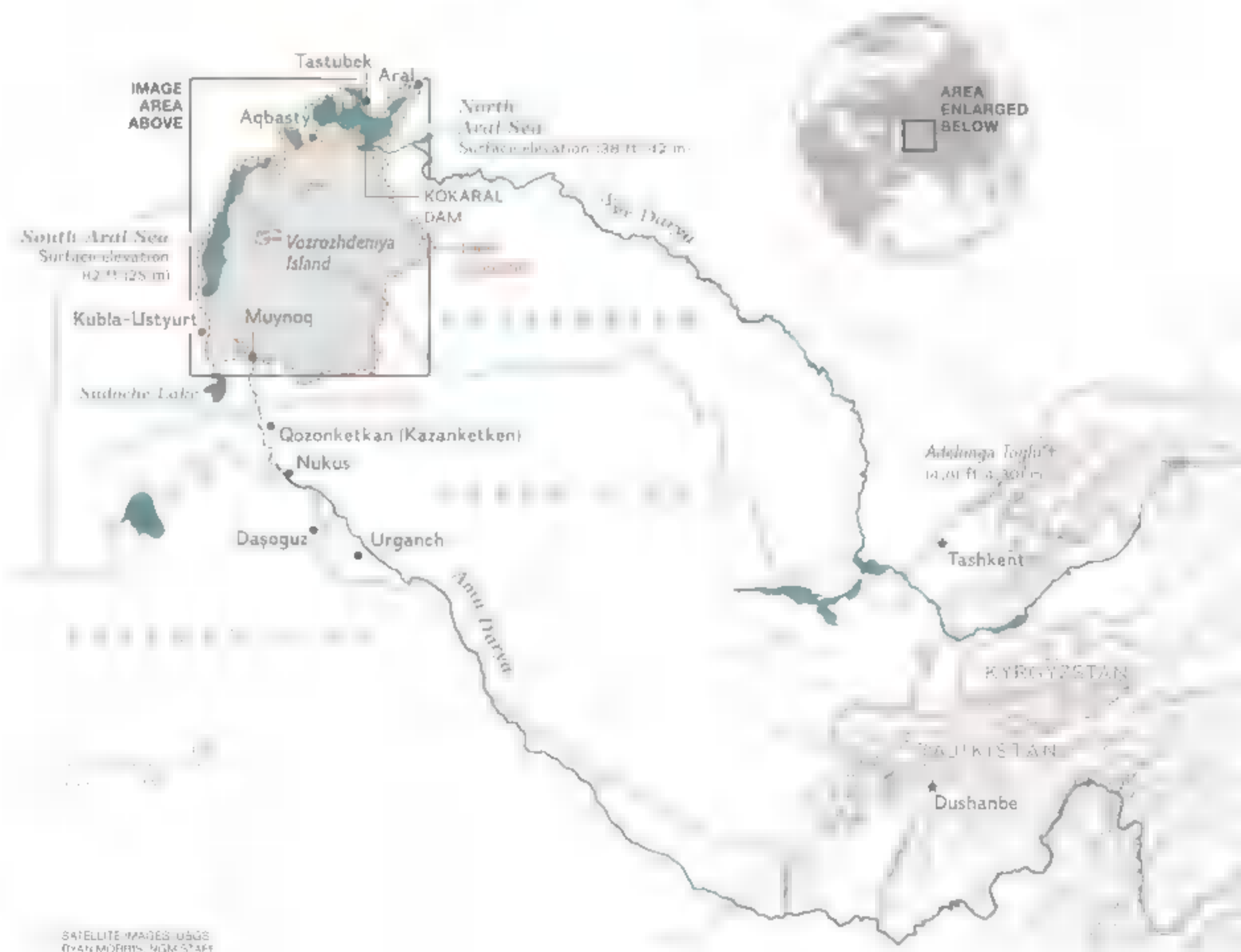
1987

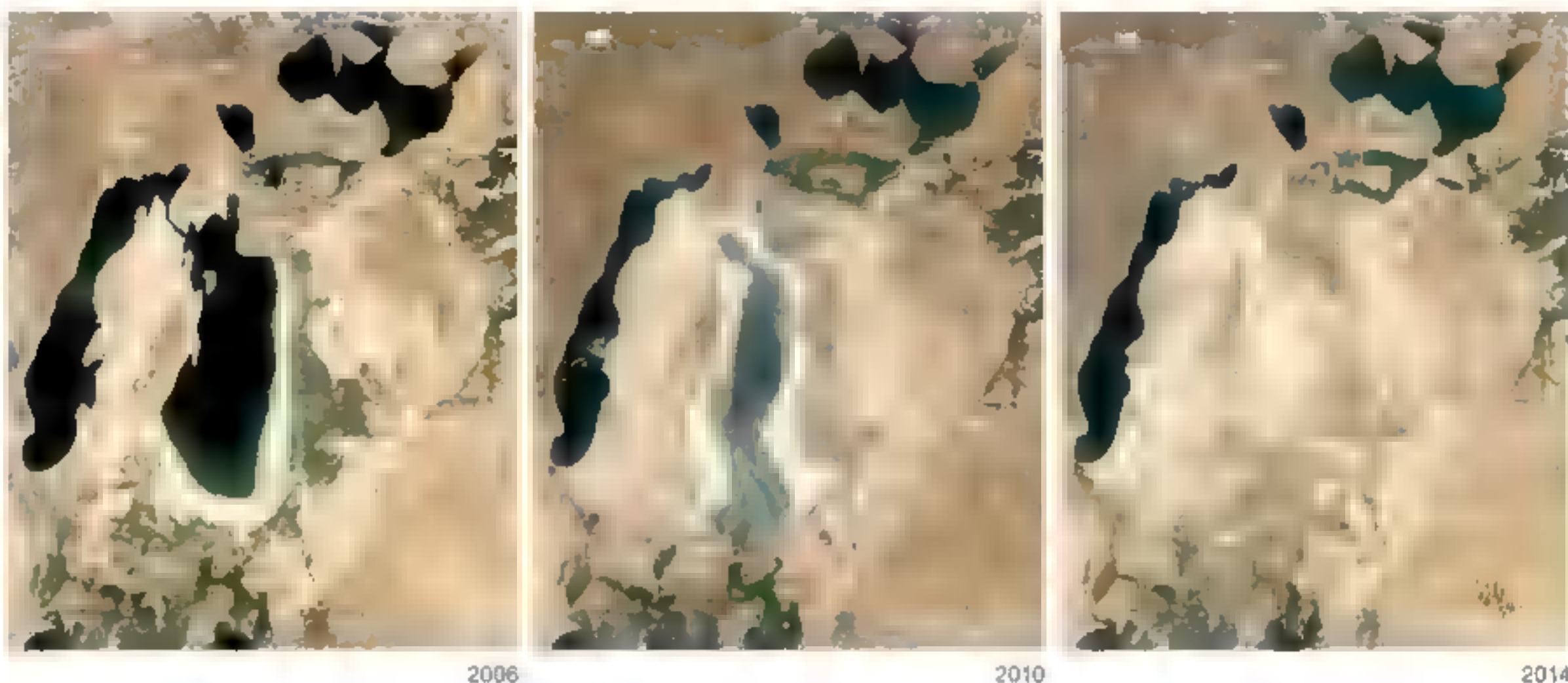


1998

Vanishing Act

Kazakhs and Uzbeks have been on different paths since 1987, when the Aral Sea split into northern and southern halves. The completion of Kazakhstan's Kokaral Dam in 2005 worsened the divide, reviving the northern sea but cutting off the southern sea from the Syr Darya river. By 2014, irrigation and drought had caused the southern Aral's eastern, shallower lobe to dry up entirely.





2006

2010

2014

China to Europe. These ancient populations of Tajiks, Uzbeks, Kazakhs, and other ethnicities prospered as farmers, fishermen, herders, merchants, and craftsmen.

Things changed after the Uzbek S.S.R. became part of the fledgling Soviet empire in the early 1920s and Stalin decided to turn his Central Asian republics into giant cotton plantations. But the arid climate in this part of the world is ill suited to growing such a thirsty crop, and the Soviets undertook one of the most ambitious engineering projects in world history, hand-digging thousands of miles of irrigation canals to channel the water from the Amu Darya and Syr Darya into the surrounding desert.

“Up until the early 1960s the system was fairly stable,” explained Philip Micklin, when I reached him by phone. As a geography professor at Western Michigan University, Micklin spent his career studying water management issues in the former Soviet Union and made about 25 trips to Central Asia, starting in the early 1980s. Over the years he watched the Aral Sea’s demise firsthand. “When they added even more irrigation canals in the 1960s, it was like the proverbial straw that broke the camel’s back,” he said. “Suddenly the system was no longer sustainable. They knew what they were doing, but what they didn’t realize was the full

range of the ecological consequences—and the rapidity with which the sea would vanish.”

By 1987 the Aral’s water level had dropped drastically, splitting it into two bodies of water: a northern sea, which lies in Kazakhstan, and a larger southern sea lying within Karakalpakstan. In 2002 the southern sea got so low that it too split into separate eastern and western seas. Last July the eastern sea dried up entirely.

The only bright spot in this dire saga is the recent recovery of the northern sea. In 2005, with funding from the World Bank, the Kazakhs completed an eight-mile dam on the northern sea’s southern shore, creating a fully separate body of water, fed by the Syr Darya. Since the dam was built, the northern sea and its fishery have come back much more quickly than expected. But the dam has cut off the southern sea from one of its crucial water sources, sealing its fate.

“The saddest and most frustrating thing about the tragedy of the Aral Sea is that the Soviet officials at the Ministry of Water who designed the irrigation canals knew full well that they were dooming the Aral,” Kamalov says. From the 1920s through the 1960s, water

Mark Synnott explored Oman rock climbing in the January 2014 issue. Carolyn Drake photographed shamans for a December 2012 story.



Each year, boats used to haul fish are left on the beach every year. This one has been rusting near the former Uzbek port of Yangi-Yul since the Aral dried up in the 1990s.

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A Kazakh fisherman is carried to a boat (above) in Tastubek, on the northern part of the Aral Sea. Thanks to a dam, fishing is still possible there. But in the Uzbek village of Kubla-Ustyurt, where the sea is almost gone, locals who once fished now rely on restricted hunting for income (above right).

officials often cited the work of Russia's most famous climatologist, Aleksandr Voeikov (1842-1916), who once referred to the Aral Sea as a "useless evaporator" and a "mistake of nature." Bluntly put, the Soviet wisdom of the day contended that crops were more valuable than fish.

The cotton harvests continue today. Each fall about two million of Uzbekistan's 29 million citizens "volunteer" to pick millions of bushels of the nation's cotton crop. The country virtually shuts down while government employees, schoolchildren, teachers, doctors, nurses, engineers, and even senior citizens are bused to the fields to reap their daily quota.

"Uzbekistan is one of the only places we know of in the world where forced labor is actually organized and enforced by the government, and the president himself is acting as a trafficker in chief," said Steve Swerdlow, director of the Central Asia bureau of Human Rights Watch.

"Can you imagine," says Kamalov, turning to me from the front seat of our Land Cruiser, "that 40 years ago the water was 30 meters deep [98 feet] right here."

Our driver points through the windshield to a thick brown cloud blowing across the desert. A minute ago there was nothing there; now I'm being told to quickly roll up my window. Seconds later we're engulfed in noxious dust that quickly infiltrates the vehicle. The dust stings my eyes, and I can taste the heavy salt, which instantly makes me sick to my stomach.

This whirlwind is but one of many ecological consequences that the Soviet planners didn't predict. "The geochemists thought that as the sea dried, a hard crust of sodium chloride would form on the surface and there wouldn't be salt storms," Micklin said. "They were dead wrong."

Besides toxic levels of sodium chloride, the dust is laced with pesticides such as DDT,



Soviet officials often cited Russia's most famous climatologist, Aleksandr Voeikov, who called the Aral a "mistake of nature."

hexachlorocyclohexane, toxaphene, and phosalone—all known carcinogens. The chemicals have worked their way into every level of the food chain.

Today Karakalpakstan registers esophageal cancer rates 25 times as high as the world average. Multidrug-resistant tuberculosis is a major problem, and respiratory diseases, cancers, birth defects, and immunological disorders are widespread.

Perhaps even more frightening is the revelation that the Aral Sea once was home to a secret Soviet biological weapons testing facility. Located on Vozrozhdeniya Island—which, now that the sea is gone, is no longer an island—the facility was the main test site for the Soviet military's Microbiological Warfare Group. Thousands of animals were shipped to the island, where they were subjected to anthrax, smallpox, plague, brucellosis, and other biological agents.

The U.S. State Department, concerned that rusting drums of anthrax could fall into the wrong hands, sent a cleanup team there in 2002. No biological agents have been found in the dust since then, but sporadic outbreaks of plague afflict the surrounding region.

As we continue toward the sea, we pass dozens of oil and natural gas rigs that punctuate what is otherwise a brittle, pancake-flat desert of sun-bleached sand. According to Kamalov, the rigs started appearing as soon as the sea began to recede, and each year a few more are erected. "Obviously, they provide a massive disincentive for the government to do anything that might cause the sea to refill," he says.

For hours we bump along on rutted dirt tracks. Other than the white sand and the blue sky, the only colors I can make out are the pale green of lonesome saxaul bushes and the pink of occasional tamarisk shrub blossoms.







A villager in Aqbasty, Kazakhstan, bathes in an ancient hot spring piped into a bathhouse (above)—one of the few water sources left after decades of irrigation and evaporation. Aqbasty used to be on the shore of the Aral Sea. Today it's seven miles inland. Muynoq, Uzbekistan (above right), is even less fortunate. With the sea receding and little vegetation to bind the soil, dust storms are common.

Finally a silvery line sparkles on the horizon, growing larger until we arrive at a Chinese encampment of several yurts set up on the edge of the sea. They are here to harvest *Artemia parthenogenetica*, a type of brine shrimp that is the only living creature left in the sea. When the Aral was healthy, the water was brackish, with a salinity level of 10 grams per liter (the world's oceans range from 33 to 37 grams per liter). Today the salinity exceeds 110 grams per liter, making it deadly to every species of fish.

Near the shoreline the muddy sand is wet, like a beach with an ebbing tide. But the Aral doesn't have a perceptible tide—what we're seeing is the sea actually receding before our eyes.

"Whatever you do, don't stop," yells Kamalov, as he plows through the knee-deep quicksand, wearing only his underwear. I plod along behind until the water reaches my knees. I try

to swim, but my legs float up to the surface, making it impossible to kick. "Just lie on your back," says Kamalov. I do, and the sensation is like that of lying on a pool floaty. My head rests on a water pillow. I hardly break the surface.

That night we camp on the plateau and cook dinner over an open fire built with dead saxaul branches. Sitting on a Persian carpet looking out over the sea, Kamalov pours shots of vodka.

WHEN THE SEA WAS HEALTHY and fishermen plied its fertile waters, moisture evaporated off the lake each day. "Now instead of water vapor in the atmosphere, we have toxic dust," says Kamalov, as he downs a shot with a grim set to his wizened face.

Since the Soviet Union collapsed, the five "Stans" have often found themselves with conflicting agendas when managing their region's most precious resource. Complicating matters,



"Now instead of water vapor in the atmosphere, we have toxic dust," says Yusup Kamalov, as he grimly downs a vodka shot.

the Amu Darya and Syr Darya trace their courses through several different countries, and each claims ownership of the waters that flow through its territory. In hopes of working together to solve Central Asia's chronic water shortage, the Stans in 1992 formed the Interstate Commission for Water Coordination. Its discussions tend to revolve around two central questions: Who owns the water, and what responsibility do the upstream countries have to protect the resource for those downstream?

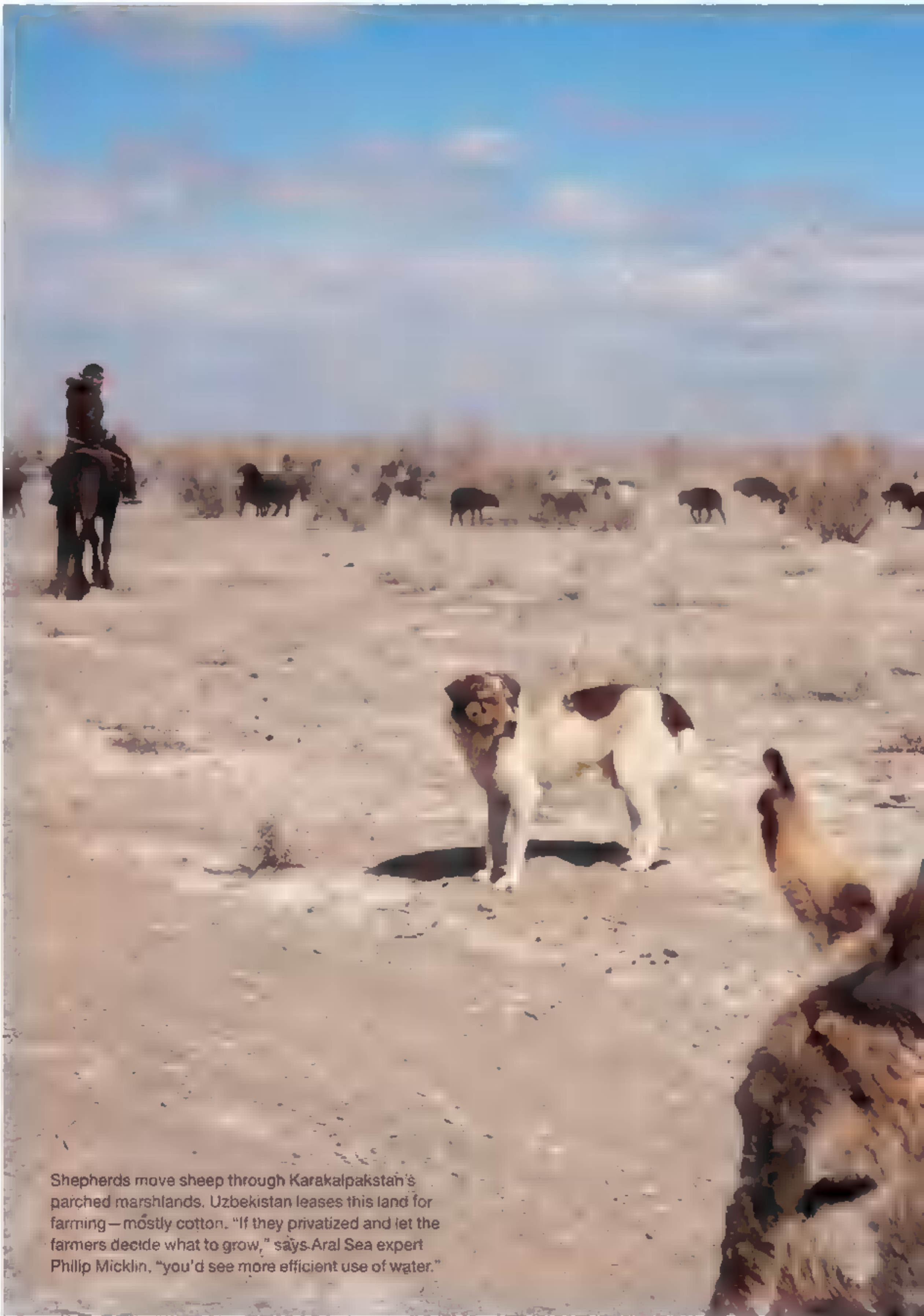
In the case of the Aral Sea, the inhabitants of Karakalpakstan, one of Uzbekistan's poorest regions, appear to have no say about what happens to the water of the Amu Darya upstream, as other countries lay claim to it. "This is discrimination due to geographic location," says Kamalov. "That water belongs to the Aral."

Every expert I interviewed predicted that Uzbekistan's portion of the Aral Sea would

not be refilled in any foreseeable human time frame. It's a point Kamalov seems resigned to.

He loathes the policy that is killing the sea of his homeland. But he confesses that when the fall cotton harvest arrives in a few weeks, he will perform his national service, just as he has done every fall for 50 years. (According to Swerdlow, who directed the Uzbekistan office of Human Rights Watch until the government expelled the organization in late 2010, if Kamalov failed to "volunteer," he could be fired from his job or arrested.) "No one is exempt," Kamalov notes. "You can be 90 years old with one eye and one leg and you still must pick."

Worried about publishing Kamalov's frank comments, I ask him, again, if he is comfortable going on the record. "In Karakalpakstan we are all afraid of Tashkent," he replies, referring to the Uzbek capital. "And personally, I'm sick of it." □



Shepherds move sheep through Karakalpakstan's parched marshlands. Uzbekistan leases this land for farming—mostly cotton. "If they privatized and let the farmers decide what to grow," says Aral Sea expert Phillip Micklin, "you'd see more efficient use of water."



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Bug-Eyed

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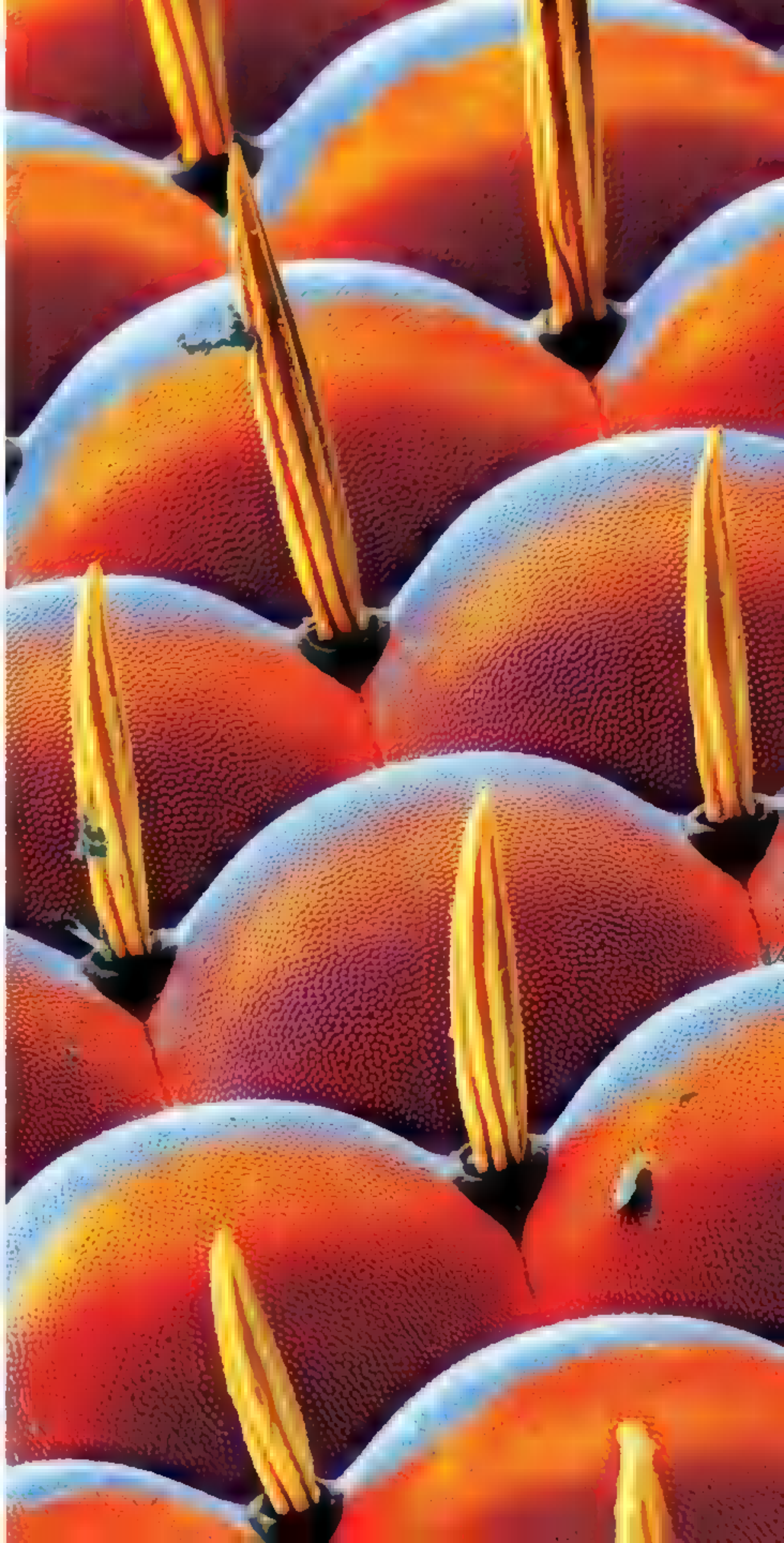
MARTIN OEGGERLI

The eye is an organ of extreme perfection. I have a strong interest in evolution, and eyes have developed stunning adaptations over time. This mayfly is a male with what are called turban eyes—greatly enlarged eyes at the top of the head in the shape of a turban. The male uses his eyes to scout for the silhouette of a female in the dim light of dusk. He doesn't even have a working mouth. If you live for only one day, as adult males usually do, you don't need to eat. But you do need tremendous eyes to find a female before you die.

I am a cancer researcher, but I also work as a science photographer under the name "Micronaut." The "micro" is because I specialize in shooting very small things using a scanning electron microscope at the School of Life Sciences in MuttENZ, Switzerland. "Naut" is because I feel like an astronaut with the scanner, flying along and making discoveries. The scanner creates black-and-white images that can take a week for me to enhance with color. Research like this is not just scientifically important—it is extremely beautiful. □

The turban eye allows for low-light vision and is found only in some male mayflies.

The fruit fly has a compound eye, a tightly packed collection of single lenses that gives the fly a gridlike view of the world. Scientists suspect the bristles may help protect the lenses, which have no eyelids, from dirt and debris.





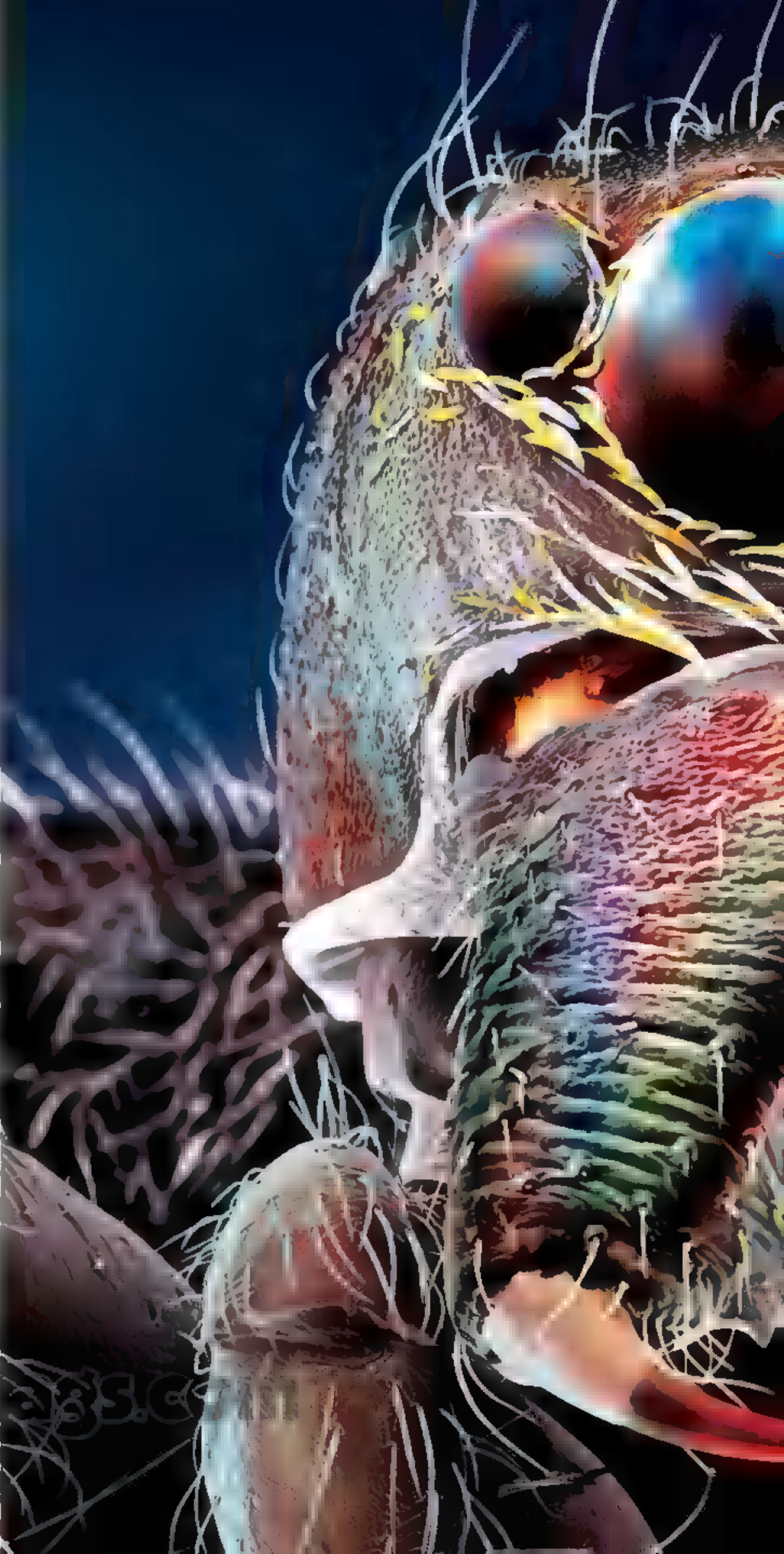
The book scorpion, so called because it likes to live in old books, has a primitive set of eyes equipped with only a few receptors. Some species lack external eyes altogether and use receptors just below the skin to detect light.





The jumping spider has eight eyes in total, giving it an almost 360-degree view of its surroundings. Its eyes have unique retinas that help it gauge distance. The small predator can leap distances more than ten times its size.

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